



DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

NEW ZEALAND
JOURNAL OF SCIENCE
AND
TECHNOLOGY

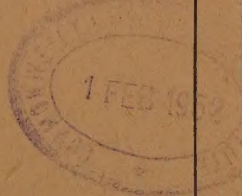
A. AGRICULTURAL RESEARCH SECTION

VOLUME 33.—No. 4

DECEMBER, 1951

Printed for the Department of Scientific and Industrial Research, Wellington,
by
Coulls Somerville Wilkie Ltd., Dunedin, N.Z.

DECEMBER 1951



NEW ZEALAND

Journal of Science and Technology

VOLUME 33, No. 4, 1951

(AGRICULTURAL RESEARCH SECTION)

CONTENTS

	PAGE
Digestibility Trials with <i>Paspalum dilatatum</i> . <i>M. R. Coup</i> and <i>A. A. Dunlop</i>	1
Studies in Monozygotic Cattle Twins. <i>John Hancock</i>	17
Land-ress Taint in Cream and Butter—IV. <i>F. H. McDowall</i> , <i>I. D. Morton</i> and <i>A. K. R. McDowell</i>	30
Land-ress Taint in Cream and Butter—V. <i>F. H. McDowall</i> , <i>A. K. R. McDowell</i> , <i>I. D. Morton</i> , <i>J. A. Singleton</i> and <i>J. J. O'Dea</i>	35
Land-ress Taint in Cream and Butter—VI. <i>F. H. McDowall</i> , <i>J. A. Singleton</i> and <i>J. J. O'Dea</i>	51
Pasteurization of Cream at High Temperatures in the Vacreator Vacuum-Pasteurizer in Relation to the Quality of Butter. <i>F. H. McDowall</i> , <i>J. A. Singleton</i> and <i>J. J. O'Dea</i>	53
Spray Treatments with D.D.T. for Control of Codling Moth (<i>Cydia pomonella</i> L.) in Apple Orchards. <i>G. G. Taylor</i>	60
Mineral and Nitrogen Status of Dougherty Apple Leaves and Fruit Under Different Fertilizer Treatments. <i>Joyce Watson</i>	66
Soil Disinfection. <i>H. Jacks</i>	71
Pea-wilt in New Zealand. <i>I. A. M. Cruickshank</i>	75

NOTICES

SUBSCRIPTIONS.—Subscriptions payable in advance. Series A, 10s. per annum; Series B, 10s. per annum; A and B, 15s. per annum. Single copies, 2s.; postage, 1d. Subscriptions should be paid by money-order, postal note, bank note or cheque, and should be forwarded to the Publications Officer, Department of Scientific and Industrial Research, P.O. Box 562, Dunedin. Cheques should be made payable to the Department of Scientific and Industrial Research, and when payable at banks other than in Dunedin should have exchange (6d.) added. Subscribers are requested to furnish their full names and addresses.

CORRESPONDENCE.—All communications relative to the Journal should be addressed to the Editor, Department of Scientific and Industrial Research, Wellington.

NEW ZEALAND
JOURNAL OF SCIENCE
AND
TECHNOLOGY

Editor: N. A. Marris, M.Sc., B.Com.

Assistant Editor: M. O'Connor, M.Sc.

Department of Scientific and Industrial Research, Wellington

VOL. 33, SEC. A

DECEMBER 1951

NUMBER 4

DIGESTIBILITY TRIALS WITH *Paspalum dilatatum*

M. R. COUP and A. A. DUNLOP, Ruakura Animal Research Station,
Department of Agriculture, Hamilton

(Received for publication, 2 March 1950)

Summary

(1) The results of ten digestibility trials with paspalum of varying stages of maturity are reported and paspalum is compared with pasture, silage and hay as a fodder for dairy cows.

(2) The nutritive value in terms of Digestible Organic Matter, Digestible Protein, and Starch Equivalent, decreases as paspalum matures. With the exception of Ether Extract, the Digestibility of all constituents also shows a steady decrease with advancing maturity.

(3) It is concluded that:—

(a) Young paspalum is comparable to summer-grown, mixed dairy pasture in digestibility and nutritive value.

(b) Paspalum of intermediate maturity is comparable to silage.

(c) The mature paspalum as used in these trials resembles hay in nutritive value.

(d) From a nutritional point of view paspalum could be used instead of silage as a standby feed in autumn.

(4) The influence of weather conditions, management, and soil fertility on the nutritive value is discussed.

INTRODUCTION

Paspalum dilatatum is a grass widely used in some tropical and sub-tropical countries because of its ability to grow well under high temperature, rainfall, and humidity conditions. The level of dairy production attained by cows fed on *Paspalum* under such conditions suggests that its nutritive quality is of a reasonable standard. In New Zealand it grows freely only in the warmer areas of the northern half of the North Island where it produces a large bulk of fodder during the summer and autumn, and continues to grow even under relatively dry conditions. Of especial interest is the practice in North Auckland where excess growth is frequently not grazed, but carried over, voluntarily or involuntarily, as a type of standing hay for use as a winter feed reserve.

In the United States paspalum has been referred to by Morrison¹ who terms it Dallis grass, while Briggs² in addition to quoting analyses on material from various Pacific Islands and from New South Wales,

has given an extensive account of its use on Guam Island. Koppers, Rusoff and Seath³ report a series of analyses, including protein, on this grass grown under a rotational grazing system. Paspalum is considered to be one of the most desirable introduced grasses in Hawaii⁴ where its ability to grow in dry periods was noted⁵. Hamblyn⁶ deals with its use and management in New Zealand.

Despite these records of analyses of paspalum, the only exact information on the nutritive value, as determined by digestibility trials, appears to be the report of two such trials in Tanganyika by French⁷. In view of the importance of this grass in the northern dairying areas of New Zealand it was decided to attempt to overcome this lack of nutritional data by carrying out a series of digestion trials with paspalum at various stages of growth. Ten such trials have been completed, and this paper records the results.

EXPERIMENTAL METHODS

In the Waikato district in which this Station is located, temperatures fall too low for paspalum to be a naturally dominant pasture species and some difficulty was experienced in obtaining an even approximately pure sward for experimental purposes. For this reason, it was necessary to specially select and manage areas from which to cut experimental material.

Three such areas (Nos. 1, 2 and 3) were used to supply material for the trials reported here, the details of their history and management being as follows:—

Area 1 (1942-43 Season): This area had been a temporary military camp subject to heavy trampling. After being vacated about 22 December 1942, it was kept closed to stock for two months, during which time paspalum came to the fore. On material from this area it was initially planned to carry out three digestibility trials at the young, intermediate and mature stages of growth, but as it was not practicable to cut sufficient of the young growth, it was possible to study only the intermediate and mature stages. It seemed likely that young material would become available as regrowth from this area after cutting, but the autumn proved to be so excessively dry that the paspalum made insufficient growth during the remainder of the season. Area 1 thus provided materials for Trials A and B only.

Area 2 (1943-44 Season): This area was chosen for a trial at the young stage because the aftermath of a silage crop cut in late November 1943 came away initially as pure paspalum. As the trial progressed, however, regrowth of cocksfoot and white clover overtook the paspalum, making the result not representative of pure paspalum. It was nevertheless fairly typical of much Waikato summer dairying pasture where paspalum is becoming dominant. (In contrast, the feeds for all other trials were at least 90-95 per cent pure paspalum.) This material was fed in Trial C.

Area 3 (1943-44 Season): This area was selected in the latter part of 1943 because of its high percentage of paspalum, and was subsequently managed with the aim of developing a pure paspalum stand for a series of trials during late summer and autumn. It was grazed periodically by sheep during spring and early summer, and in mid-November it was topped and raked to remove seedheads of other species. It was again topped on 7 December and thereafter closed to stock until the start of the trials. Rainfall throughout November, December and January was

very sparse and some two months elapsed before there was sufficient growth on the area to allow the series of trials to commence. It should be stressed that the material used in the first of these trials (D and E) was grown in a dry period when the yield of fodder from the normal ryegrass, white clover, and cocksfoot pastures at Ruakura was negligible. Trials D to I were run as a continuous series on progressively maturing paspalum from this area. These trials were so arranged that, taking their pre-periods into account, they overlapped by one week, thus ensuring that digestibility data would be available throughout the paspalum growing season.

A further trial (J) was carried out with "young stage" paspalum which had come away as regrowth on the portion cut for Trial D, one month earlier.

Finally a portion uncut after the completion of Trial I was held over in an attempt to simulate the standing paspalum roughage often used as winter feed in Northland. This material constituted the feed for Trial K which was carried out in July 1944. For comparison with Trial K a typical Northland winter paspalum sample was obtained by an experienced fields instructor, and its chemical composition determined.

In all digestibility trials with paspalum the basic system was a six-day pre-period followed by a ten-day faeces collection period, two dry non-pregnant Jersey cows being used in each case. Owing to labour shortage no collection of faeces was made during the weekends although feeding continued normally. Each trial thus involved approximately three weeks' feeding. Collection of the faeces was carried out by the bag method of Ballinger and Dunlop⁸ though the equipment at that time was at a somewhat less complete stage than they describe and occasional accidents caused some days' collections to be incomplete or contaminated with urine so that it was not always possible to calculate the digestibility results over a full ten-day period. The number of days used in calculation for each cow is shown in the full results. (Appendix C.)

The faeces samples for Trial H were unfortunately destroyed by fire, with the result that no digestibility data are available for this trial. In two trials, namely Trials I and K, the agreement between individual animals in each trial is particularly poor. No definite reason can be advanced for this lack of agreement though it may be due to the fact that no faeces collections were made during the week-ends. Full details of the treatment and analysis of the feeds and faeces samples are given in Appendix B.

RESULTS

The results of ten completed digestibility trials with paspalum are given in Table I. Digestible organic matter (D.O.M.), digestible protein (D.Pr.) and starch equivalent (S.E.), are used as the main basis of comparison in this paper. All figures are expressed on a dry matter basis.

Statistical treatment of the organic matter digestibility coefficients of these and other trials in which the same technique was adopted has indicated that at the 5 per cent level of probability a difference in digestibility greater than 5.8 per cent with two animals per trial, and greater than 4.6 per cent with three animals per trial, is necessary for significance. At the 1 per cent level these values became 7.8 per cent and 6.4 per cent respectively. In the interpretation of these results a difference of 5.8 per cent may be taken as the criterion of significance.

TABLE 1. RESULTS OF DIGESTIBILITY TRIALS WITH PASPALUM.

Trial No.	Description and date:	Chemical Composition (% Dry Matter Basis)					Digestion Coefficients*					Feed Value % of Dry Matter.									
		Ash.	Pr.	E.E.	C.F.	N.F.E.	Group I - Relatively Young Material.			O.M.	Pr.	E.E.	C.F.	N.F.E.	D.O.M.	D.Pr.	S.E.				
		Group II - Intermediate Type Material																			
J.	4-6 week's regrowth 20/3 - 31/3/44. Lgh 3-4in Paspalum Dominant after- math 22/12/43 - 6/1/44	11.2	15.0	3.2	25.8	44.8	78.1	75.7	57.3	80.8	78.8	69.3	11.4	62.3							
C.	1 Month's growth	9.6	18.2	4.3	22.8	45.1	75.1	75.1	56.4	74.0	77.4	67.9	13.7	61.9							
		Group III - Mature Material																			
D.	1st Stage: 8/2 - 23/2/44 Dense & leafy: Lgh 4in Grown 2 months.	9.9	9.9	2.8	26.1	51.3	71.4	61.4	39.9	72.8	74.4	64.4	6.1	55.6							
E.	2nd Stage: 22/2 - 8/3/44 Still more mature than D.	10.8	10.2	2.3	28.5	48.2	67.5	60.0	22.3	70.9	69.2	60.2	6.1	50.0							
F.	3rd Stage: 9/3 - 22/3/44 Fresher than E due to Feb. rains	10.9	9.9	2.5	29.6	47.1	71.4	62.8	51.4	75.3	71.8	63.6	6.2	54.4							
A.	Mid Stage: 24/2 - 5/3/43 Lgh 5-9in. Very green, some head. Grown 2 months.	9.3	11.0	2.8	31.1	45.8	70.1	63.4	48.7	75.1	69.6	63.6	7.0	53.2							
G.	4th Stage: 20/3 - 5/4/44 Still more mature than F.	9.5	9.4	2.3	29.9	48.9	68.6	61.3	26.7	72.1	69.7	62.1	5.8	52.1							
H.	5th Stage: 4/4 - 17/4/44	11.0	10.1	2.3	28.8	47.8	No digestibility data available.														
I.	6th Stage: 20/4 - 29/4/44 Advancing maturity, showing head and dead leafage.	11.0	9.4	2.6	28.6	48.4	62.6	56.1	32.0	67.0	63.0	55.7	5.3	46.5							
		Group III - Mature Material																			
K.	Standing, winter fed July 1944. High in dead leafage some head and some green leaf.	9.6	8.6	2.5	27.4	51.9	56.9	44.2	46.2	59.5	58.1	51.4	3.8	42.4							
B.	Mature Stage: 14/3 - 25/3/43 Lgh. 1-2 ft Many ripe seed- heads and dead undergrowth.	6.7	6.3	1.8	34.9	50.3	58.3	39.4	37.4	63.9	57.5	54.4	2.5	39.1							
	Typical Northland Winter Paspalum Sample	6.3	5.1	2.1	39.2	47.3	No digestibility data available.														

NOTE:-

*Mean of the Digestion Coefficients obtained with the 2 animals in each trial.

Pr. = Protein; E.E. = Ether Extract; C.F.

Crude Fibre; N.F.E. = Nitrogen Free Extract; O.M. = Organic Matter;

Digestible Protein; S.E. = Starch Equivalent.

D.O.M. = Digestible Organic Matter; D.Pr.

The results in Table I are arranged in order of maturity of the material fed, rather than in chronological sequence, and it is evident that the trials cover three types of paspalum:—

Group I: Relatively young material—Trials J and C.

Group II: Intermediate type material—Trials D, E, F, A, G, and I. (Table I also sets out the chemical composition data for the feed of Trial H.)

Group III: Mature material—Trials K and B, with which have been included for comparative purposes the chemical analyses of the Northland winter paspalum sample.

In Table II the average values for chemical composition, digestion coefficients and D.O.M., D.Pr., and S.E., for these three groups of paspalum are presented, together with similar values for other feeds. Thus young spring pasture and early summer mixed dairy pasture are given for comparison with young paspalum. Typical New Zealand values for autumn-grown mixed dairy pasture, silage and hay are presented for comparison with Group II and Group III classes of paspalum⁹.

It is at once apparent from these tables that the chemical composition, the digestibility, and hence the nutritive value, all decrease as the grass matures. In the ensuing discussion these points are considered in greater detail, a comparison is made between paspalum and other types of feed, and finally the influence of factors such as weather and management on the nutritive value of paspalum are briefly dealt with.

Effect of Stage of Growth

(a) *On Chemical Composition*: The most important point revealed by the group average values in Table II is the fall in protein content as the material matures. Thus, Group I contained 16.6 per cent of protein, Group II, 10.0 per cent, and Group III, 7.4 per cent. A similar tendency is shown by ash and fat, whereas crude fibre and nitrogen-free extract show a steady increase. In the still more mature Northland sample (Table I) the protein is even lower (5.1 per cent), while the crude fibre has risen to 39.2 per cent.

(b) *On Digestibility*: With the exception of ether extract, all constituents show a steady decline in digestibility with advancing maturity. The fall in digestion coefficients between trials G (O.M., 68.6) and I (O.M., 62.6) is particularly to be noted. By the time Trial I was run—one month after Trial G—the maturity of the paspalum stand was so advanced that seedheads and dead leaves were apparent.

(c) *On Digestible Nutrients and Food Value*: The group-average values in Table II show that there is a considerable progressive decrease in nutritive value from Groups I to III. For example, per 100 lb dry matter, the Group II material is 7 lb lower in D.O.M., 6.4 lb lower in D.Pr., and 10 lb lower in S.E., than the young Group I material. The Group III material is in turn lower than the Group II by 9 lb D.O.M., by 3 lb D.Pr., and by 11 lb S.E. This lowered feed-value due to stage of growth is again readily illustrated in Table I by comparing Trial D, in which the feed was dense and leafy and only two months old, with Trial I, in which the feed was four months old and seedheads and dead leafage were appearing. The D.O.M. has dropped from 64.4 per cent to 55.7 per cent, D.Pr. from 6.1 per cent to 5.3 per cent, and S.E. by 9 lb from 55.6 per cent to 46.5 per cent.

TABLE II.
COMPARISON OF PASPALUM WITH OTHER NEW ZEALAND FEEDS.

Description	Chemical Composition (% Dry Matter Basis)				Digestion Coefficients						Feed Value % of Dry Matter			
	Ash.	Pr.	E.E.	C.F.	N.F.E.	O.M.	Pr.	E.E.	C.F.	N.F.E.	D.O.M.	D.Pr.	S.E.	
Average Values for Groups.														
Group I (J & C) Relatively young paspalum:	10.4	16.6	3.8	24.3	45.0	76.6	75.4	56.8	77.4	78.1	68.6	12.5	62.1	
Group II (D-I & A) Intermediate type paspalum	10.2	10.0	2.5	29.0	48.3	68.6	60.8	36.8	72.2	69.6	61.6	6.1	52.0	
Group III (K & B) Mature Paspalum	8.2	7.4	2.2	31.2	51.1	57.6	41.8	41.8	61.7	57.8	52.9	3.1	40.8	
Young Spring Pasture Sept. - Oct. 3-4 wks growth 1 trial.	9.6	21.7	5.3	22.0	41.4	83.2	79.4	66.0	84.5	86.7	75.2	17.2	71.0	
*Mixed dairy pasture Nov-Dec. 1946. Av. values 10 trials	9.1	16.4	4.6	24.9	45.1	74.7	73.7	55.8	72.6	77.9	67.9	12.1	62.0	
*Mixed Dairy pasture. Feb-Mar. 1947 Av. Values 8 trials	9.6	14.3	3.7	26.5	45.9	62.8	62.3	34.7	60.2	66.3	56.8	8.9	46.9	
Average quality Pasture Silage 8 Trials.	9.5	11.6	4.3	35.8	38.8	66.7	43.6	50.8	78.9	63.9	60.4	5.0	49.1	
Average quality Pasture Hay. 3 Trials.	7.6	8.4	2.0	33.3	48.7	55.5	51.5	48.2	57.7	54.9	51.2	4.3	32.6	

*Normal Eye-gress, white clover, cocksfoot type.

NOTE:- Pr.= Protein; E.E.= Ether Extract; C.F.= Crude Fibre; N.F.E.= Nitrogen Free Extract;
O.M.= Organic Matter; D.O.M.= Digestible Organic Matter; D.Pr.= Digestible Protein;
S.E.= Starch Equivalent.

The extent of this decline in digestible nutrients with maturity of the herbage is shown in Table III, where the difference between the nutrient content of the paspalum in certain trials is expressed as a percentage of that of the earlier member in each pair. Under "Interval" is given the time between the start of the trials compared. Changes in the digestible nutrients as between the three groups of paspalum are also included.

TABLE III. CHANGE IN DIGESTIBLE NUTRIENTS (EXPRESSED AS PERCENTAGE OF FIGURES RECORDED FOR YOUNG MATERIAL)

(a) Between Trials:		D.O.M.	D.Pr.	D.C.F.	S.S.E.
	Interval				
A to B	18 days	- 14.5	- 64.5	- 4.5	- 26.5
G " I	31 "	- 10.3	- 8.6	- 11.1	- 10.7
I " K	2½ months	- 7.7	- 28.3	- 15.1	- 8.8
(b) Between Groups:					
1 - 11	—	- 10.2	- 51.2	+ 11.2	- 16.3
11 - 111	—	- 14.1	- 49.2	- 7.9	- 21.5

* D.C.F.—Digestible Crude Fibre.

With only one exception, the digestible nutrients and starch equivalents tabulated show a decrease with maturity. This decrease is most marked in digestible protein.

These observations may therefore be summarized by stating that as paspalum matures its nutritive value decreases, owing not only to a fall in the amount of the major nutrient substances present, but also to a decrease in their digestibility.

In our experiments all the paspalum showing much seedhead was three months or more old, so that this may be taken as the maximum period for which this grass may be allowed to grow before its food value falls rapidly.

Comparison of Paspalum with Mixed Pasture and Other Fodders

(a) Chemical Composition:

The average of the results of 10 trials on mixed dairy pasture grown in the months of November and December is given in Table II. From these figures it is seen that the chemical composition of young paspalum is remarkably similar to that of the mixed dairy pasture growing at this time. When it is considered that the requirements of these experiments, as previously explained, made it impracticable to start digestibility trials until the paspalum had already grown to a stage when it could be cut in quantity, it appears reasonable to expect that still younger, quickly growing paspalum, which would in practice be grazed at this period, would have compared even more favourably with mixed pasture grown at the same time. It might indeed even approach the composition of the young spring pasture, which is some 5 per cent higher in protein than the young paspalum tested (Table II).

Comparison of the chemical composition of the Group II (intermediate type) paspalum fed off during the autumn with that of February-March, mixed dairy pasture indicates that the paspalum is much lower in protein but higher in crude fibre and nitrogen-free extract. Table II also gives average values for 8 trials with silage, the fodder that autumn-grown paspalum might be used to replace in farming practice. In a comparison of the chemical composition of these two fodders it is seen that while the paspalum is lower in protein and considerably lower in crude fibre, it is much richer in nitrogen-free extract.

It is interesting to compare the chemical composition of the mature paspalum with that of hay and silage. Average values for three trials with hay are also given in Table II. While more nearly resembling hay than silage, the mature paspalum has a lower protein- and fibre-content, but rather more nitrogen-free extract than has hay, as indicated in the following table:—

		Protein.	Fibre.	Nitrogen-free
		%	%	extract.
				%
Paspalum		7.4	31.2	51.1
Hay	---	8.4	33.3	48.7

It should be pointed out here that, judged both on appearance and on chemical composition, the feed for Trial K, which it was hoped would simulate the winter paspalum often used as a type of standing hay in Northland, was far from typical of the latter product. Thus the Northland sample contained a large amount of stalk and no green leafage whatever, and had 5.1 per cent of protein and 39.2 per cent crude fibre, compared with 8.6 per cent and 27.4 per cent respectively for the material in Trial K.

(b) Digestibility:

Comparison of the digestion coefficients of paspalum with those of mixed pasture shows that young material is better than the November-December mixed pasture but not as good as young spring pasture. Again, the intermediate type of paspalum is better than the February-March mixed pasture. The mature material had digestion coefficients of a similar order to those of hay, but while slightly higher for fibre and N.F.E., they are considerably lower for protein.

(c) Digestible Nutrients and Feed-Value:

The young regrowth paspalum of Group I is shown to be almost identical in feed-value with the November-December mixed pasture.

The intermediate type autumn paspalum is some 5 lb higher in D.O.M., 5 lb higher in S.E., and approximately 3 lb lower in D.Pr. than the February-March mixed pasture. It is important to compare the autumn-grown Group II paspalum with silage which is the feed it would most probably be called upon to replace under dry conditions when mixed pasture was unavailable. In terms of D.O.M., D. Pr., and S.E., paspalum is the more valuable fodder especially as regards digestible protein. Even the poorest material in this group, that of Trial I with 5.32 lb D.Pr., is still slightly better in this respect than average silage in which the D.Pr. content is 5.0 lb.

The mature material of Group III compares well with average quality hay as regards overall digestibility and energy value, but it is considerably lower in digestible protein. Thus, while, like hay, it would no doubt be useful as a maintenance food, it would be of little use for milk production.

Although no digestibility data are available for the still more mature typical Northland product, the chemical composition, as indicated earlier, suggests that its food-value would be even lower than that of average hay.

Effect of Weather, Soil Fertility and Management on Nutritive Value
 (a) *Weather:*

These experiments bring out certain aspects of the effect of both temperature and rainfall on the quality and growth of paspalum in the Waikato.

Temperature: Since paspalum is very sensitive to frost, its time of active growth is commonly restricted in the Waikato to a period between November and May. In competition with less frost-tender grasses it is thus generally prevented from becoming a naturally dominant species. In addition, the early onset of winter cold may not allow paspalum to reach full maturity, but rather preserves the grass in a fairly green palatable form. Comparison of the material used in Trial K with the sample from the warmer Northland district illustrates this point.

Rainfall: From Appendix A it is seen that in the 1943 season (from mid-December 1942 to April 1943) rainfall was particularly sparse—approximately half the ten-yearly averages for these months. Thus, for the whole of the period that Area 1 was closed up, there was little rainfall. This retarded the growth of the paspalum, and it was not possible to commence Trial A until toward the end of February, while continued dry weather in March prevented, on the cut areas, any regrowth that would provide material for a paspalum trial at the young stage of growth.

The following season, 1943-44, the months of November, December and January were particularly dry, and at the beginning of December paspalum was the only feed showing any growth at all. In spite of this fact, it was possible to run only one digestibility trial with paspalum before the beginning of February. This one trial, viz. Trial C run in December and January, was conducted on material which had come away as a dominantly paspalum aftermath following cutting for silage. Trials D, E, and F—the first of the continuous series run in this season—demonstrate the effect of rainfall on paspalum after a dry period.

	D.O.M.		
	%		
Trial D (prior to rain) --- --- ---	64.4		
Trial E (during period of rain) --- ---	60.2		
Trial F (subsequent to rain) --- ---	63.6		

In this example advancing maturity had lowered the D.O.M. in Trial E as compared with D but in Trial F this effect has been counteracted by the new growth due to rainfall, and the D.O.M. had again risen.

(b) *Soil Fertility:*

The effect of soil fertility on the growth of paspalum is indicated by a comparison of the material used in Trials A and B with that used in Trials D, E and F. Although these two sets of trials were conducted in different years, the paspalum was grown at the same time of the year and under similar weather conditions, but on areas which differed in soil fertility. The material in Trials A and B grown on the soil of higher fertility showed considerably more seedheads than did the material of Trials D, E, and F, suggesting that lower fertility retards development and tends to prevent seedhead formation. The rate of development on the soil of higher fertility is indicated by the fact that the material of Trial B was a particularly mature feed, 1-2 ft high, with many ripe seedheads and much dead undergrowth (digestible organic matter, 54.4),

whereas that of Trial A, cut only three weeks earlier, was only 5.9 in. high and, although containing some heads, was still very green. This gave a digestible organic matter of 63.6.

(c) *Management:*

It is apparent that, since nutritive value falls with advancing maturity, a system of management which will maintain a vigorous growth of less mature herbage is desirable. In this respect the effect of cutting is demonstrated by comparing results of Trial J with those for Trials D, E and F.

TABLE IV. EFFECT OF CUTTING ON FEED VALUE OF PASPALUM

Trials.	D.O.M.	D.Pr.	S.E.
	%	%	%
J	69.3	11.4	62.3
D	64.4	6.1	55.6
E	60.2	6.1	50.0
F	63.6	6.2	54.4

Trial J was conducted with the regrowth obtained on the area cut 4.6 weeks earlier to provide herbage for Trials D, E and F. Cutting alone produced a feed with significantly higher amounts of digestible nutrients, especially of digestible protein—a particularly important constituent for the milking cow in autumn.

The effect of cutting is again illustrated in Trial C—the aftermath of a silage crop (see Table I). It may be noted that in both Trial C and Trial J the paspalum regrowth is as high in food value as good mixed pasture (see Table II).

While topping as it would be carried out in farming practice was not specifically tested, these results produced by closely cutting the paspalum suggest that topping would have a similar beneficial effect.

DISCUSSION

The most striking feature of this work on paspalum is the relatively low protein content of the feeds. This may well be a result of maturity and, in some cases, of dry weather.

In this connection the protein figures on paspalum given by Kupperts, Rusoff and Seath³ in the United States are of interest. The samples used were taken at approximately monthly intervals from plots closely grazed in rotation by dairy cattle to a height of about 3 inches. The figures reported showed the average protein content followed a regular downward trend, from a maximum of 18.6 per cent in early spring to a minimum of 9.1 per cent in the hot, dry, late summer, rising again to over 14 per cent in the two succeeding months. Thus, even in paspalum maintained as relatively short young growth, hot dry weather depressed the protein content. It should be noted that the maximum protein value of 18.6 per cent is very similar to the maximum value recorded in this investigation, while the minimum value of 9.1 per cent is only slightly lower than the average for the intermediate type material examined by the authors. In the only cases where the material examined was slightly younger, e.g., Trials C and J, the protein values rose sharply, and it seems reasonable to expect that with paspalum at still younger stages of growth, even higher protein values would be obtained. Similar reasoning might also be applied to protein digestibilities, which in general closely parallel the protein contents.

From Tanganyika, French⁷ reported figures for two digestibility trials run on paspalum up to a foot high and showing a few flowering heads. As regards maturity, this material should be comparable to that of Trials A and G reported in this paper. The organic-matter digestibility coefficients of 67.9 and 69.2 are very similar, but the starch equivalents (46.7 and 48.5), protein contents (7.2 and 6.6), and digestible-protein values (of 3.3 in each case), even on a silica-free basis, are lower than those reported by the authors.

CONCLUSIONS

The ten completed digestibility trials carried out on paspalum at Ruakura show that as the paspalum matures its nutritive value decreases. Thus, comparing the three types of material examined, viz. the young regrowth of Trials J and C, the intermediate stages of Trials D-I, and the rank growth of Trials K and B, it is found that there is:—

- (1) a marked decrease in protein content with a corresponding increase in fibre;
- (2) a steady decrease in the digestion coefficients of all constituents—with the exception of ether extract;
- (3) a decrease in total digestible organic matter, digestible protein and starch equivalent.

Somewhere about the flowering and seed-setting stage paspalum appears to fall rapidly in food value—from our experiments this appears to be when the paspalum is 3 or more months old.

That cutting has a markedly beneficial effect on the quality of the feed is shown by comparison of the young regrowth of Trial J with the material cut earlier from the same area for Trial D. Thus cutting alone has increased the D.O.M. from 64 to 69 per cent, the starch equivalent from 56 to 62 per cent, and, what is more important, almost doubled the digestible protein. While no data are available on the effects of grazing it is reasonable to expect that it would have a similar effect to cutting.

Young regrowth material is almost identical, both as regards chemical composition and feeding value, with mixed dairy pasture grown during the months of November-December. It is considered that the really young paspalum growth, which is coming to the fore at this period and is the material actually being consumed by the grazing animal, would prove superior even to early summer mixed pasture.

While the intermediate type of paspalum which had been grown from 2 to 4 months is better than mixed pasture grown over the same period in respect to digestible organic matter and energy value, it is considerably lower in digestible protein content. It has been shown, however, that the autumn growth of paspalum is superior to silage in all respects. It appears therefore that it could well be used instead of silage as a stand-by when mixed pasture is not available as a result of drought conditions.

This conclusion does not constitute any advocacy for not making silage on the farm, since it is based on nutritional data only and does not include consideration of farm management practice.

The two trials K and B show that mature paspalum obtained under experimental conditions in the Waikato is comparable with average quality New Zealand hay though with a lower digestible protein content and a higher starch equivalent. It is stressed that the mature feeds used

were not strictly comparable with the typical Northland standing paspalum. The poorer composition of this typical Northland sample, together with a probable loss of palatability, would point to such material being of doubtful feed value.

Additional work on this class of fodder, especially on the grass in its young quickly-growing stage, still requires to be carried out. Further, the yields given by paspalum would also appear to warrant investigation, as this might well place it in an even more favourable light than this paper has indicated.

ACKNOWLEDGMENTS

The authors wish to acknowledge the advice and assistance given by Mr. C. E. Ballinger, who was responsible for the field management of the pastures used in this work. The assistance rendered by a number of technical officers both in the field and the laboratory is also acknowledged. Thanks are also due to Mr. P. S. Syme, who collected the Northland paspalum sample.

APPENDIX A

RAINFALL FOR PERIODS AFFECTING PASPALUM TRIALS (Monthly totals in inches)

Ten Year	Nov.	Dec.	Jan.	Feb.	Mar.	April
Average:	4.24	3.09	4.03	3.32	2.34	3.44
1942-43	—	5.17	2.89	1.17	0.86	2.54
1943-44	3.86	1.36	1.50	5.80	5.85	4.79

Dates of Closing of Areas and Periods of Trials.

- Area I. Closed up 22/12/42.
Trial A. 24/2 - 5/3/43; Trial B. 14/3 - 25/3/43.
- Area II. Cut for Silage late November, 1943.
Trial C. 22/12/43 - 6/1/44.
- Area III. Closed up 8/12/43.
Trial D. 8/2 - 23/2/44; Trial E. 22/2 - 8/3/44.
Trial F. 9/3 - 22/3/44; Trial G. 20/3 - 5/4/44.
Trial H. 4/4 - 17/4/44; Trial I. 20/4 - 29/4/44.
Trial J. 20/3 - 31/3/44; Trial K. 6/7 - 15/7/44.

APPENDIX B.

TREATMENT AND ANALYSIS OF FEED AND FAECES SAMPLES

The methods of analyses used were essentially those outlined in the A.O.A.C. Methods of Analysis¹⁰.

Two separate samples of fixed weight were taken from the feed each day. One for chemical composition and the other for the determination of dry matter. The daily feed-composition samples were spread out thinly on trays and dried in the forced circulation drier with an air temperature of approximately 40°C. At the end of trial these feed-composition samples were bulked. The dry-matter samples were given a preliminary drying in a water oven at 98°C., and a final 24 hours drying in an electric oven at 105°C. They were then cooled in a desiccator, and weighed to give the daily dry matter of the feed. A single

aliquot sample of the faeces was taken daily and the dry matter determined as for the feed sample. At the end of the trial these faeces dry-matter samples were bulked for the respective animals, and used for the determination of faeces composition.

Before analysis both feed and faeces samples were ground in a C. & N. hammer mill, using a perforated screen of 1/32 inch mesh. The ground samples were stored in air tight jars.

Dry Matter:

For this determination a sample representing approximately 2 g of dry matter was dried for 24 hours in an electric oven at 105°C.

Ether Extract: The sample used in the dry-matter determination was transferred to a weighed sintered glass crucible (porosity A1-A2) and extracted for 16 hours in a Soxhlet with anhydrous sulphuric ether. The weight of the dried crucible plus residue thus allowed the calculation of the crude fat by difference.

Crude Fibre: The fat-free residue was transferred to a 600 ml squat type Pyrex beaker fitted with a round-bottom flask as insertion condenser. Boiling times, and acid and alkali strengths were those prescribed in the A.O.A.C. methods, and filtration was done through cloth. After drying to constant weight in a vitrosil basin, the residue was ignited in an electric muffle furnace.

Ash: A.O.A.C. method using 1 - 1.5 g of sample and ashing in an electric muffle furnace at 580°C.

Crude Protein (Nx 6.25):

This was estimated by the method of Ma and Zuazaga¹¹. Approximately 0.1 g of sample was accurately weighed out and digested 45 - 75 minutes. The digest was made up to 50 ml from which a 5 ml aliquot was taken for distillation. Following Ma and Zuazaga the distillate was collected in 2 per cent boric acid and titrated directly with N/100 sulphuric acid using the mixed indicator—bromocresol green and methyl red—as specified.

REFERENCES

- (1) MORRISON, F. B. (1938): Feeds and Feeding, 20th ed., New York, Morrison Publ. Co., p. 303.
- (2) BRIGGS, G. (1921): *Guam Agr. Expt. Sta. Bull. No. 1.*
- (3) KUPPERS, J. R., RUSOFF, L. L., and SEATH, D. M. (1948): *J. Agr. Res.* 77, 55-63.
- (4) *Hawaii Agr. Expt. Sta.* (1939): *Annual Rept.*
- (5) *Hawaii Agr. Expt. Sta.* (1940): *Annual Rept.*
- (6) HAMBLYN, C. J. (1936): *N.Z. J. Agr.* 53, 257-62.
- (7) FRENCH, M. H. (1941): *J. Expt. Agr.* 9, 23-28.
- (8) BALLINGER, C. E. and DUNLOP, A. A. (1946): *N.Z. J. Sci. Tech., A*, 27, 509-20.
- (9) Unpublished data, Nutrition Section, Ruakura Animal Research Station.
- (10) Methods of Analysis of the Association of Official Agricultural Chemists (1930): 3rd Ed., p. 277.
- (11) MA, T. S., and ZUAZAGA, G. (1942): *Ind. and Eng. Chem., Anal. Ed.* 14, 280-2.

APPENDIX C.

FULL ANALYTICAL AND DIGESTIBILITY DATA FROM PASPALUM TRIALS.

(a) Chemical composition of feed;			(b) Digestibility coefficients;				(c) Digestible Nutrients.										
Trial No.	Description	Cow No.	Ash,	Pr. E.E. (on dry matter basis)	Cl.F.	N.F.E. as off-ered.	% Dry Matter	Dry Matter (lb.)	Digestibility Coefficients	D.O.M. % of dry Matter	S.E.	Residue as % of Feed Offered (Wet Basis)	Days Per Cow				
J.																	
	4-6 weeks regrowth		(a)	11.2	15.0	3.2	25.8	44.8									
	20/3 - 31/3/44		(b)	-	72.7	52.2	78.7	76.9									
	Fresh, comparatively young, from earlier cut areas. Length 3-4"	36	(c)	-	10.9	1.7	20.3	34.4	19.37	63.92	18.43	71.2	75.8	67.3	60.2	Nil	10
			(b)	-	78.7	62.4	82.9	80.7									
		16	(c)	-	11.8	2.0	21.4	36.1	19.09	57.26	14.57	74.6	80.4	71.4	64.4	Nil	9
C.																	
	Paspalum dominant after-math. 22/12/43 - 6/1/44		(a)	9.6	18.2	4.3	22.8	45.1									
	Commencing as paspalum	36	(b)	-	75.8	59.4	74.8	78.2	24.37	97.48	28.28	71.0	76.0	68.7	62.4	Nil	10
	changed over to cocksfoot		(c)	-	13.8	2.5	17.1	35.2									
	and white clover		(b)	-	74.5	53.4	73.2	76.7	23.79	95.14	31.42	67.0	74.3	67.1	61.4	0.03	10
	1 Months growth	16	(c)	-	13.6	2.3	16.7	34.6									
D.																	
	1st Stage: 8/2 - 23/2/44		(a)	9.9	9.9	2.8	26.1	51.3									
	Short, dense, leafy, slow grown material.	48	(b)	-	62.0	35.7	72.4	74.0	25.83	90.83	30.23	66.7	71.0	64.0	55.1	0.93	10
	Length approx. 4"		(c)	-	6.1	1.0	18.9	38.0									
	Grown 2 months.		(b)	-	60.8	44.1	73.2	74.8	26.59	80.63	26.08	67.7	71.9	64.8	56.1	1.56	10
		30	(c)	-	6.0	1.2	19.1	38.4									
E.																	
	2nd Stage: 22/2 - 8/3/44		(a)	10.8	10.2	2.3	28.5	48.2									
	Paspalum of increasing maturity, still slow grown	44	(b)	-	60.9	31.8	72.4	70.9	24.02	100.84	40.70	59.6	69.2	61.7	51.8	0.02	12
	despite satisfactory rainfall		(c)	-	6.2	0.7	20.6	31.1									
		7	(b)	-	59.1	12.9	69.4	67.5	24.02	100.84	39.23	61.1	65.7	58.6	48.2	0.02	12
			(c)	-	6.0	0.3	19.8	32.5									

Trial No.	Description	Cow No.	Ash.	Pr.	E.E.	C.F.	N.F.E.	% Dry Matter in feed as offered.	Dry Matter (lb.) consumed.	Digestibility Coefficients	D.O.M. % of dry matter.	S.E. Residue as % of Feed Offered (Wet basis)	Days per Cow
F.	3rd Stage: 9/3 - 22/3/44. Fresher than for Tr.E. due to effect of February rains. Approx. 3 months' growth.	38	{ a } 10.9 { b } - { c } -	{ a } 9.9 { b } 61.3 { c } 6.1	{ a } 2.5 { b } 50.6 { c } 1.3	{ a } 29.6 { b } 76.0 { c } 22.5	{ a } 47.1 { b } 71.4 { c } 33.6	21.03	66.24	62.7	63.4	54.2	9
		82	{ a } - { b } - { c } -	{ a } 64.3 { b } 52.2 { c } 6.4	{ a } 74.6 { b } 22.1 { c } 1.3	{ a } 72.2 { b } 34.0 { c } -		21.00	72.63	64.7	63.8	54.5	10
A.	Mid Stage: 24/2 - 5/3/43 Some head, but still very green. Grown approx. 2 months. Length 5-9"	16	{ a } 9.3 { b } - { c } -	{ a } 11.0 { b } 63.4 { c } 7.0	{ a } 2.8 { b } 48.6 { c } 1.4	{ a } 31.1 { b } 73.5 { c } 22.9	{ a } 45.8 { b } 68.4 { c } 31.3	23.46	100.59	63.9	62.5	52.1	9
		36	{ a } - { b } - { c } -	{ a } 63.4 { b } 48.8 { c } 7.0	{ a } 76.6 { b } 23.8 { c } 1.4	{ a } 70.9 { b } 32.5 { c } -		23.43	87.08	67.4	64.6	54.2	9
G.	4th Stage: 20/3-5/4/44. Still more mature than Trial F. paspalum	7	{ a } 9.5 { b } - { c } -	{ a } 9.4 { b } 62.2 { c } 5.8	{ a } 2.3 { b } 39.5 { c } 0.9	{ a } 29.9 { b } 72.2 { c } 21.6	{ a } 48.9 { b } 70.2 { c } 34.4	20.58	64.84	65.4	62.7	53.0	9
		41	{ a } - { b } - { c } -	{ a } 60.5 { b } 13.9 { c } 5.7	{ a } 72.1 { b } 21.5 { c } 0.3	{ a } 69.2 { b } 33.9 { c } -		21.05	66.31	61.4	61.4	51.2	9
H.	5th Stage. 4/4 - 17/4/44		{ a } 11.0	10.1	2.3	28.8	47.8						
I.	6th Stage: 20/4-29/4/44 Advancing in maturity. 36 Some Head. Dead leafage showing up at bottom of pasture.	82	{ a } 11.0 { b } - { c } -	{ a } 9.4 { b } 50.3 { c } 4.7	{ a } 2.6 { b } 13.3 { c } 0.3	{ a } 28.6 { b } 64.9 { c } 18.6	{ a } 48.4 { b } 59.4 { c } 28.8	20.36	49.89	52.8	52.4	42.7	7
			{ a } - { b } - { c } -	{ a } 61.8 { b } 50.7 { c } 5.8	{ a } 69.1 { b } 19.8 { c } 1.3	{ a } 66.5 { b } 32.2 { c } -		20.97	58.52	60.6	59.1	50.2	8

Trial No.	Description	Cow No.	Ash, Pr. (on dry matter basis)	E.M. C.E. N.F.E. in Feed (on dry matter basis)	% Dry Matter in Feed as Offered.	Dry Matter (lb) Consumed	Voided	Digestibility Coefficients D.M.	O.M.	D.O.M. S.E. % of dry matter	Residue as % of Feed Offered (Wet Basis)	Days Per Cow
K.	Standing Paspalum fed in winter, July 1944. High in dead leafage and some head but still some green leaf in evidence.	(a)	9.6	8.6	2.5	27.4	51.9					
		(b)	-	36.4	41.1	53.3	52.3					
		(c)	-	3.1	1.0	14.6	27.2					
		(b)	-	52.1	51.4	65.8	63.9					
B.	Mature Stage: 14/3-25/3/43 Many ripe seed heads and dead undergrowth Length 1-2 ft.	(a)	6.7	6.3	1.8	34.9	50.3					
		(b)	-	38.1	35.3	64.8	57.5					
		(c)	-	2.4	0.6	22.6	28.9					
		(b)	-	40.7	39.3	63.0	57.5					
	Northland winter paspalum - very dry and dead, high proportion of stalk, no green leafage.	(a)	6.3	5.1	2.1	39.2	47.3					
		(b)	-	-	-	-	-					
		(c)	-	-	-	-	-					
		(b)	-	-	-	-	-					

Note: No chemical composition or dry matter determinations were made on the feed residues, the raw weights being simply subtracted from the weight of feed offered. Only in Trials A and B were the residues appreciable.

STUDIES IN MONOZYGOTIC CATTLE TWINS

V. UNIFORMITY TRIALS—GROWTH

By JOHN HANCOCK, Ruakura Animal Research Station, Department of Agriculture, Hamilton

(Received for publication, 9 October, 1950)

Summary

1. The trend of the within-set weight differences in a sample of 10 sets of monozygotic twins is discussed.
2. The calculation of twin-efficiency values of size and growth gave the following result :

(a) Body weights	26
(b) Absolute growth rates.	13
(c) Instantaneous relative growth rate.	11
(d) Linear body measurements.	5.30
3. The reasons for variations in twin-efficiency values are briefly discussed.

INTRODUCTION

THIS paper which covers size and growth aspects is a continuation of a series^{1,2} in which an attempt is being made to assess the relative efficiency of monozygotic cattle twins as experimental animals.

The accurate measurement of body size and growth of large herbivorous animals, and especially ruminants, is difficult because of uncontrollable variations due to ruminal, intestinal and bladder contents. Another difficulty is due to the fact that individual animals do not grow at a constant rate at any stage. Especially under New Zealand pastoral conditions growth rates are highly irregular due to the fact that the animals, almost throughout their main developmental period, are submitted to quite wide nutritional fluctuations. It is possible that polynomial equations could be fitted successfully to the resulting growth curves and thus provide, in a single expression, an accurate description of the course of growth over a long period. For the present purpose and to the practical animal investigator, however, such a procedure is not appropriate as such polynomials are not amenable to statistical analysis. In the present study an attempt has been made to overcome the inaccuracies of measurements by using averages of repeated observations to determine "true" size at any given time.

In order to provide as complete a picture as possible of the efficiency of twins in growth trials, the main period of growth has been divided, rather arbitrarily, into portions of varying length, commencing at various stages of development. The growth rates for these periods have subsequently been analysed separately or in combination with each other. The latter procedure is necessary in order to gauge the importance of the period $\times$ set interactions.

EXPERIMENTAL PROCEDURE

Although a great amount of data have accumulated at Ruakura as a result of routine growth measurements on twins born in other years, the present discussion is confined mainly to an unselected sample of ten sets of heifer twins born in the winter of 1944.

The brand numbers and birth dates are shown in Table I.

TABLE I. BRAND NUMBERS AND BIRTH DATES OF TWINS

No.	Birth Date.	No.	Birth Date.
T1-T2	10/8/1944	T17-T18	6/7/1944
T3-T4	9/8/1944	T19-T20	30/7/1944
T7-T8	14/8/1944	T23-T24	20/7/1944
T11-T12	28/8/1944	T25-T26	17/8/1944
T13-T14	22/7/1944	T29-T30	13/7/1944

The twins were born on various farms in the Waikato district and brought to Ruakura when approximately 7-10 days old. Up to the age of 8 weeks they were fed on whole-milk, which in the following 2 weeks was gradually replaced by skim milk. Weaning was commenced at 16 weeks and completed at 18 weeks of age. Up to 16 weeks, milk was fed at the rate of 12 per cent. of body weight, the quantities being adjusted weekly. Throughout the milk feeding period the calves had full-time access to good quality pasture. After weaning they were given only pasture, supplemented with hay and silage when pasture growth was inadequate. No attempt was made by preferential feeding to equalize differences occurring either between or within sets.

The calves were weighed weekly; the weights are tabulated in Table II.

TABLE II. CRUDE WEIGHTS OF TWINS

Twin No.	Weights of Twins (in lb.) at weekly ages indicated.							
	4	16	28	40	52	64	76	88
T1	65	152	287	380	428	507	623	659
T2	50	142	280	380	420	517	630	639
T3	58	190	328	424	445	525	600	576
T4	48	175	308	387	435	528	597	571
T7	60	193	314	397	460	535	648	628
T8	55	190	314	409	456	528	644	609
T11	53	170	308	390	419	458	585	585
T12	52	180	320	418	408	493	600	625
T13	70	210	335	435	477	549	676	640
T14	68	215	335	442	495	556	694	676
T17	89	219	362	472	552	621	781	778
T18	88	227	366	482	563	628	783	767
T19	83	225	358	440	495	625	690	660
T20	81	220	337	435	500	618	708	687
T23	65	195	324	416	443	516	618	636
T24	66	196	298	397	435	493	584	600
T25	63	192	326	424	479	623	655	635
T26	63	190	327	412	487	615	650	640
T29	70	187	304	408	431	514	667	652
T30	63	182	309	398	442	500	662	651

In order to save space, only four-weekly weights are given. In the following, all body weights are expressed as the moving averages of five consecutive weekly measurements. All growth rates have been computed, from the data smoothed in this manner.

The Relationship between Age and Within-set Differences.

A question frequently asked regarding the growth of monozygotic twins is whether they tend to become more or less alike as they grow older. It is important to clarify this point, not only because of implications on the usefulness of monozygotic twins in growth trials, but also because it may indicate the extent to which the result of prenatal growth restrictions persist.

In order to clarify this issue, the deviations from the mean weight of each of the 10 sets of uniformly treated twins were computed at weekly intervals. These values, expressed in absolute and relative terms are shown graphically in Figs. 1 and 2 respectively. As there was an appreciable spread in the birth dates of the sets included (see Table I), the graphs have been constructed to show, in addition to the age trend, possible effects of seasonal factors.

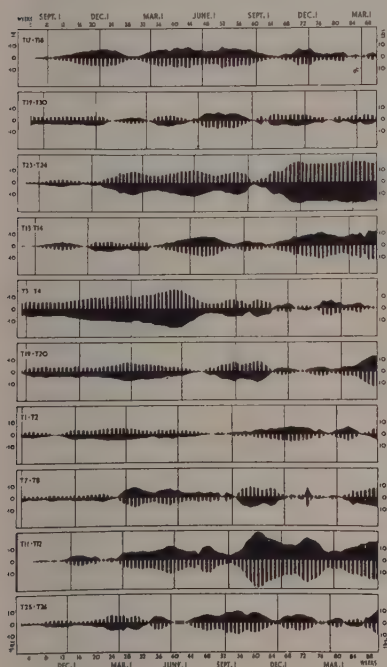


FIG. 1.—Absolute deviations (lb.) from mean set weights, shown by members of each set plotted on age and time basis.

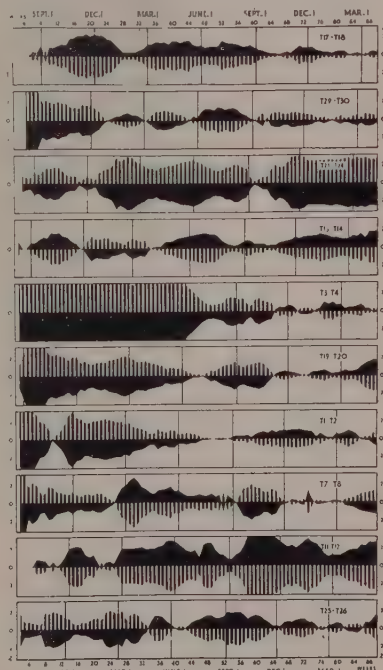


FIG. 2.—Relative deviations (%) from mean set weights shown by members of each set plotted on an age and time basis.

It is immediately obvious that the initial within-set weight differences or, indeed, differences at any time period provided a poor indication of the future weight relationship within a set of twins. The members in no fewer than seven sets interchanged position. In many cases this occurred frequently. (See, for instance, the sets T7-T8 and T25-T26). In spite of fluctuations of this type, a definite trend for absolute deviations to increase up to the age of approximately 6 months is observed. This trend is easier seen in Fig. 3, where the average within-set deviations have been graphed on a time basis.

The average absolute deviations were smallest, viz. 3.6 lb., at the first recorded weight (four weeks of age) ; they then rose continuously to reach 12 lb. at 28 weeks and thereafter fluctuated round this figure until 64 weeks when another sharp increase occurred. This last rise was partly due to the differences which existed within the sets in regard to stage of pregnancy.

The deviations on a percentage basis tended to move in the opposite direction. The majority of the sets, viz. 6, showed the greatest within-set deviations in the beginning, with a subsequent fall. Only two sets showed rising values while the deviations within the two remaining sets fluctuated irregularly. The average percentage deviations are shown in Fig. 3. The average deviations were highest at 4 weeks, viz. 2.5 per cent., dropping sharply to 1.7 per cent. at 12 weeks and decreasing thereafter slowly with minor fluctuation to 0.85 per cent. at 76 weeks. Then followed a rapid increase similar to that occurring in the absolute values. It seems that the twins in this sample tended to become relatively more alike as they grew older, although the absolute within-set differences increased to some extent.

As an inspection of Figs. 1 and 2 did not reveal any well-marked seasonal trends in the within-set deviations, no further study has been made of this aspect.

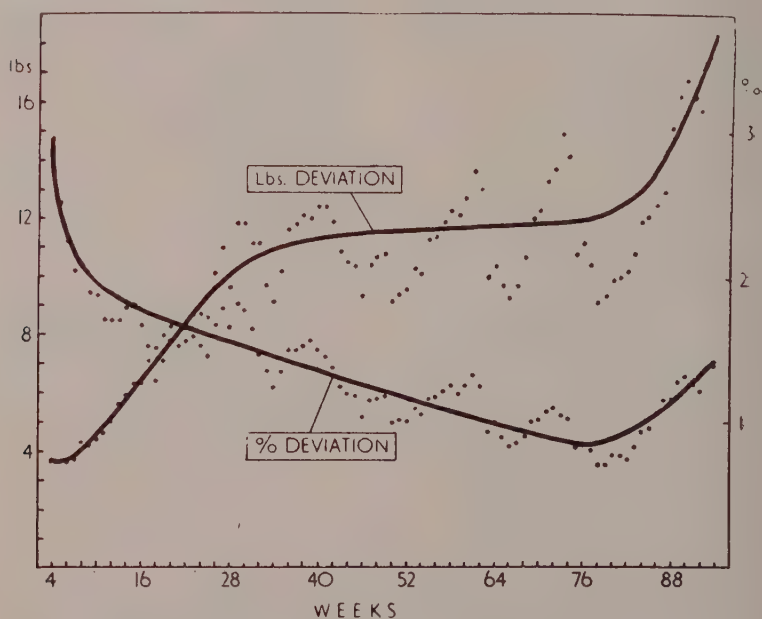


FIG. 3.—The average deviations from mean set weights plotted on an age basis.

Weight.

In order to avoid too many laborious computations only weights at 12-week intervals (beginning at 4 weeks and ending at 88 weeks) have been used in the following analysis.

Table III shows the average weights, the weights of the lightest and heaviest twin sets, the average within-set differences and the weight differences between the lightest and heaviest twins at each of the eight ages.

TABLE III. WEIGHT DIFFERENCES IN TWINS

Age Weeks.	Average Weight. (lb.)	Range between Sets. (lb.)	Difference between heaviest and lightest set. (lb.)	Average within set diff. (lb.)
4	67	51 - 89	38	3.4
16	192	174 - 226	52	6.2
28	321	300 - 363	63	10.6
40	417	379 - 480	101	12.2
52	462	423 - 553	130	8.7
64	555	499 - 624	125	10.2
76	657	591 - 778	187	11.0
88	647	589 - 770	181	14.9

By 88 weeks the initial average within-set difference had increased 4.1 times, while the range between sets of twins had increased 4.8 times. The analysis of variance set out in Table IV shows that when the variations due to age have been accounted for, the only remaining sources of variation of any importance were those due to the between-set differences and to the age $\times$ between-set interaction. The highly significant interaction between age and sets indicates that the sets at the same age occupied different positions on the weight scale relative to other sets. This is clearly seen in Fig. 4, where the weekly weights of the 10 sets of twins have been plotted on an age basis. As the within-set differences were in most cases so small that the weight curves for each twin could not have been clearly distinguished, the curves for the members of each set have been joined to form a single line at varying thicknesses. For comparison the growth curves of each twin pair are set against the heaviest and lightest animal in the sample.

The significant within-set difference was caused by two sets (T11-T12 and T23-T24) which showed small but consistent weight differences.

TABLE IV. WEIGHT DIFFERENCES IN TWINS: ANALYSIS OF VARIANCE

Source of Variation.	D.F.	M.S.	Significance.	Variance Component.	
				Actual.	(%)
Between sets	9	17308	SS	1005	4.2
Within sets	10	328	SS	35	
Ages	7	896167	SS	44761	96.7
Ages $\times$ sets	63	954	SS	453	1.0
Residue	70	47		47	
Total	159				

The twin-efficiency value calculated in a manner shown in a previous paper¹ resulted in the high figure of 26. This was due to a high coefficient of variation of 31.7 per cent. between sets of twins, relative to a fairly small within-set coefficient of 4.4 per cent.

Twin-efficiency values have also been computed for live weights at each age beginning at 4 weeks and ending at 88 weeks of age at 12-weekly intervals.

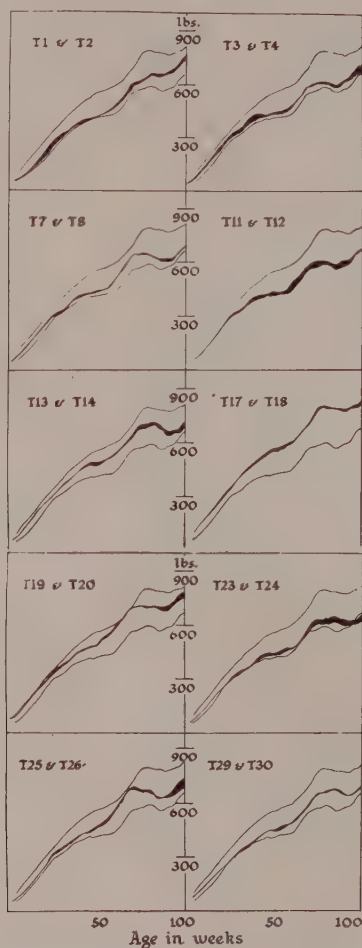


FIG. 4.—Weekly weights of 10 sets of twins plotted on an age basis (see text).

TABLE V.

Age. (Weeks)	Variance Components.		Coefficient of Variation %.		Twin Efficiency Values.
	Between Sets.	Within Sets.	Between Sets.	Within Sets.	
4	138	14	25.4	5.5	10
16	506	22	16.8	2.7	13
28	500	76	10.2	2.7	7
40	787	116	9.9	2.6	7
52	1626	47	12.4	1.5	35
64	2519	97	12.9	1.8	26
76	2848	115	11.6	1.6	25
88	2517	168	11.3	2.0	15

It is obvious that the twin efficiency values may vary quite widely with comparatively small fluctuations in the between- and within-set variances.

Absolute growth rates.

Absolute growth rates were calculated for 7 periods all beginning at 4 weeks of age but varying in length from 12 to 84 weeks. Table VI provides a comparison of the between- and within-set differences.

TABLE VI. ABSOLUTE GROWTH RATES: COMPARISON OF BETWEEN-SET AND WITHIN-SET DIFFERENCES

Period. (Weeks)	Average 12-weekly weight increase. (lb.)	Range between Sets. (lb.)	Difference between fastest and slowest growing sets. (lb.)	Average within-set difference. (lb.)
4 - 16	126	87½ - 141	53½	4.3
4 - 28	128	112 - 138	46	4.4
4 - 40	117	105½ - 130	24½	3.7
4 - 52	99	91½ - 116	24½	1.9
4 - 64	98	86 - 112½	26½	1.9
4 - 76	99	90 - 115	25	2.4
4 - 88	83	77 - 97½	20½	2.4

Up to the period 4-64 weeks, the within-set differences tended to decrease as the periods taken into calculation increased. The range between sets became progressively smaller from the shortest to the longest periods.

The analysis of variance (Table VII) showed that the variations due to between sets, within sets, periods, periods $\times$ sets, were all highly significant. The within-set differences were caused by small but consistent differences in two of the sets included. Excluding the variation caused by period differences, the between-set differences and the interaction periods $\times$ sets were the only important sources of variation.

TABLE VII. ABSOLUTE GROWTH RATES: ANALYSIS OF VARIANCE

Source of Variation.	D.F.	M.S.	Significance.	Variance Components.	
				Actual.	(%)
Between sets	9	715	SS	33.9	6.6
Within sets	10	27	SS	2.3	0.5
Between periods	6	5611	SS	395.5	84.6
Periods $\times$ sets	54	74	SS	34.8	7.5
Residue	60	4½		4.125	0.9
Total	139				

The coefficients of variation for the between- and within-set differences were 25 per cent. and 4.9 per cent. respectively. The twin-efficiency value was moderately high, viz. 13.

Although the twin-efficiency value calculated in this manner provides perhaps the best over-all picture of the usefulness of monozygotic twins in growth trials, it is of obvious interest to compute values for each period separately. Table VIII contains the pertinent information.

TABLE VIII.

Period Weeks.	Variance Components.		Coefficient of variation %.		Twin efficiency values.
	Between sets.	Within sets.	Between sets.	Within sets.	
4 - 16	223.2	14.2	17.1	3.0	16
4 - 28	67.2	12.4	9.5	2.8	5
4 - 40	45.3	10.6	8.6	2.8	4
4 - 52	55.7	2.7	10.7	1.6	21
4 - 64	74.4	4.0	12.7	2.1	19
4 - 76	51.3	4.0	10.5	2.1	13
4 - 88	36.1	4.4	8.8	2.5	8

When the growth calculations were extended over 12, 24 and 36 weeks the within-set variations were high. The twin-efficiency value, however, remained high for the first of these periods because of a very high between-set variance but dropped sharply during the two following periods as the between-set variations fell to a more normal level. When the length of the periods was increased beyond 36 weeks the within-set variations became very low which, together with fairly steady variations between sets, caused relatively high twin-efficiency values. This series illustrates well how even small fluctuations in the variances can alter materially the calculated twin-efficiency values.

Instantaneous relative growth rates.

Although the absolute growth rates are quite adequate for practical purposes, a more fundamental approach to growth phenomenon may be obtained by computing the instantaneous relative "true" growth rate as expressed by Brody's³ formula $k = \frac{dW/dt}{W}$. This formula can be applied only to the self-accelerating phase of the growth curve which in cattle ends at puberty, or approximately at six months of age. While other unpublished Ruakura data⁴ indicate that "k" is not constant for any length of time the self-accelerating phase in this sample of twins can be divided conveniently into three distinct parts. The three phases are as follows:

- (1) up to 8 weeks of age;
- (2) from 8 to 16 weeks of age;
- (3) from 16 to 24 weeks of age.

The breaks at 8 weeks may conceivably have been due to the change over from whole-milk to skim-milk feeding while the break at 16 weeks coincided with weaning.

The "k" values obtained for each twin set and animal for each period are compared in Fig. 5. The fastest and slowest growing animal in the sample, the average within-set differences and the range occurring between sets are shown in Table IX.

TABLE IX.

Period.	Average "k" value.	Range between sets.	Difference between fastest and slowest growing sets.	Average within-set difference.
- 8	0.110	0.086 - 0.172	0.086	0.007
8 - 16	0.079	0.065 - 0.096	0.031	0.003
16 - 24	0.049	0.041 - 0.060	0.019	0.002

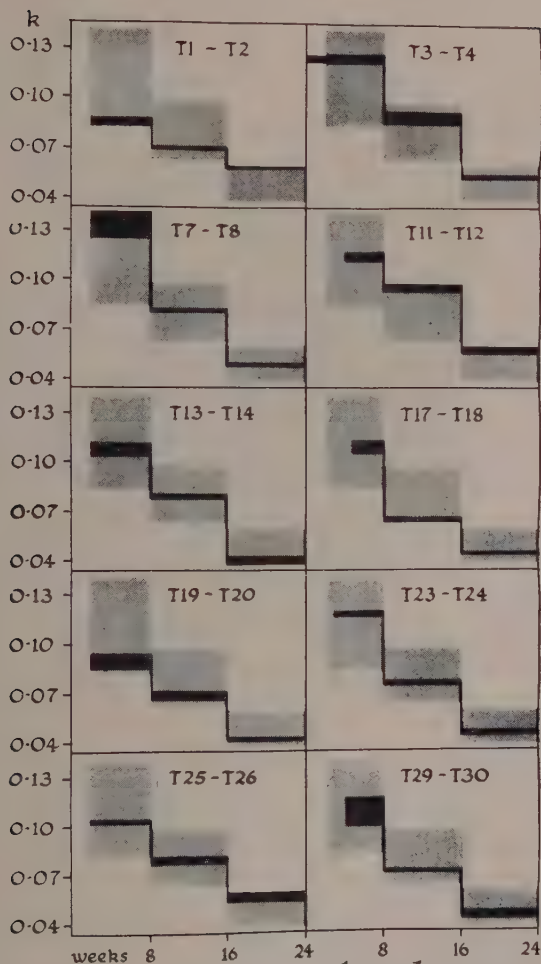


FIG. 5.—“K” values for 10 sets of twins calculated for three separate periods (see text).

The range between sets as well as the within-set differences tended to decrease with successive periods.

The analysis of variance given in Table X showed that only the variations due to periods, and the periods $\times$ set interaction were statistically significant.

The fact that the variance due to the interaction periods $\times$ sets was more than twice as great as the variance due to the differences between sets shows that the instantaneous relative growth rate of a set of twins in one period is a poor indication of its growth rate in another period. The coefficient of variation between sets was nevertheless high, viz. 24.1 per cent., while the within-set coefficient was fairly low, viz. 5.1 per cent. The twin-efficiency value was calculated as 11.

TABLE X. "k" VALUES: ANALYSIS OF VARIANCE

Source of Variation.	D.F.	M.S.	Significance.	Variance Components.	
				Actual.	(%)
Between sets	9	·00036		·000033	3·2
Within sets	10	·00002		·000001	0·1
Periods	2	·01908	SS	·000896	87·9
Periods × sets	18	·00016	SS	·000075	7·4
Residue	20	·00001		·000014	1·4
Total	59				

The results of the analysis of variance carried out separately for the three periods are shown in Table XI.

TABLE XI. ANALYSIS OF VARIANCE

Period Weeks.	Variance Components.		Coefficient of Variation %.		Twin efficiency value.
	Between Sets.	Within Sets.	Between Sets.	Within Sets.	
- 8	·000187	·000035	18·36	5·36	5
8 - 16	·000089	·000005	17·31	2·82	18
16 - 24	·000048	·000003	20·29	3·47	16

The differences between sets were highly significant in all three periods. It is obvious that the relatively low twin-efficiency value in the first period was due to a greater variability within sets than occurred in the two other periods.

Body Measurements.

Body measurements were taken on an unselected sample of 12 sets of monozygotic twin heifers. The animals were born within a fortnight and had been reared together from birth onwards. The following measurements were taken :—

- (1) Height at withers.
- (2) From point of shoulders to ischium.
- (3) Depth of chest just behind elbow joint.
- (4) From point of hips to ischium.
- (5) Width of hips.
- (6) Heart girth just behind elbow.
- (7) Girth of paunch at the end of last rib.
- (8) Length of poll to point of muzzle.
- (9) Width of forehead.
- (10) Length of lower jaw.
- (11) From top of zygomatic arch to lower jaw.
- (12) Length of tail.

Two independent operators repeated the measurements on three successive days. In the following, the analysis and discussions are based on the average values of six replicated measurements.

Table XII compares the average within-set differences with the range occurring between sets, while the individual values obtained have been plotted in Figs. 6(a) and 6(b) as intra-class correlation scattergrams.

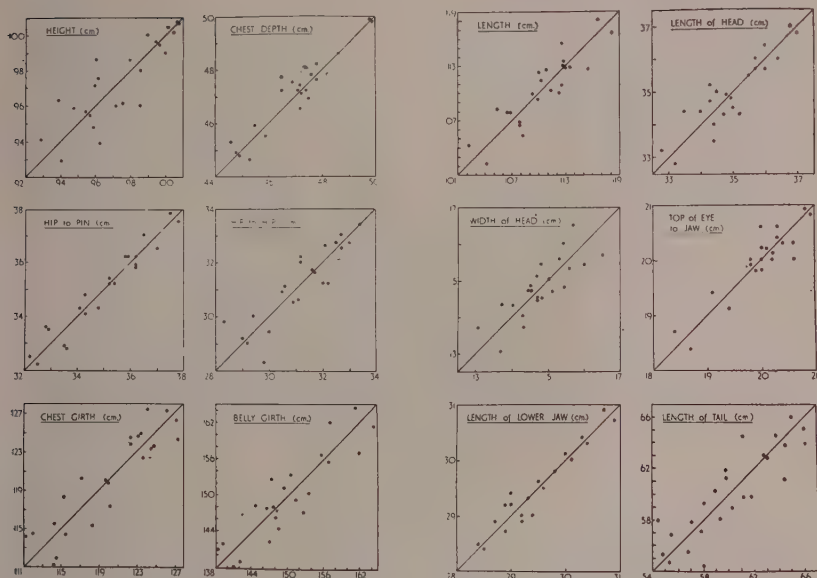


FIG. 6a AND 6b.—Intraclass correlation scattergrams of 12 body measurements.

TABLE XII. COMPARISON OF WITHIN-SET DIFFERENCES WITH RANGE OCCURRING BETWEEN SETS

Measure- ment.	Average. (cm.)	Range between sets. (cm.)	Difference between extreme sets. (cm.)	Average within-set difference. (cm.)
1	97.4	93.5 - 100.4	6.9	1.2
2	110.4	103.2 - 117.3	14.1	1.5
3	47.1	44.9 - 49.9	5.0	0.4
4	35.1	32.4 - 37.7	5.3	0.4
5	31.3	29.1 - 33.4	4.3	0.5
6	120.3	112.7 - 126.7	14.0	2.0
7	149.9	140.5 - 163.0	22.5	2.8
8	35.0	33.0 - 36.9	3.9	0.4
9	14.8	13.9 - 16.1	2.2	0.4
10	29.5	28.5 - 30.4	1.9	0.2
11	20.0	18.5 - 20.9	2.4	0.2
12	60.0	55.0 - 65.5	10.5	1.4

The longer body measurements tended to be associated not only with greater ranges but also with greater within-set differences.

The differences between sets were highly significant for all body measurements. The twin-efficiency values ranged from 5 (width of head) to 30 (hip to ischium), but most of them were sufficiently near to 10 to warrant the conclusion that the efficiency values for all body measurements are approximately that value.

The analysis of variance is shown in Table XIII.

TABLE XIII. COMPARISON OF WITHIN-SET DIFFERENCES WITH RANGE OCCURRING BETWEEN SETS: ANALYSIS OF VARIANCE

Measure- ment.	Variance Components.		Coefficient of Variations %		Twin efficiency values.
	Between Sets.	Within Sets.	Between Sets.	Within Sets.	
1	4.9	.8	3.4	0.9	6
2	14.0	1.4	4.9	1.1	10
3	2.0	0.1	4.3	0.8	15
4	2.5	0.8	6.4	0.8	32
5	1.9	0.2	6.5	1.5	9
6	23.1	2.3	5.8	1.3	10
7	47.9	4.9	6.7	1.5	10
8	1.1	0.1	4.3	0.9	10
9	0.5	0.1	7.3	2.3	5
10	0.4	0.02	3.2	0.5	19
11	0.3	0.03	4.2	0.9	11
12	10.9	1.5	8.0	2.1	7

DISCUSSION

In their attempt to evaluate the usefulness of monozygotic twins for growth experiments Bonnier *et al.*⁵ arrived at the conclusion that twins are approximately 50 times more efficient than calves selected at random in trials covering growth from the 80th to 180th day of life.

Bonnier's twin-efficiency value, however, was computed as the $\frac{\text{between-sets}}{\text{within-sets}}$ mean square ratio while the method used in the present

series, involves the calculation of the $\frac{\text{between-sets}}{\text{within-sets}}$ variance component ratio. On this latter basis Bonnier's value is approximately halved and thus becomes 25. This is still much greater than the value of 5 obtained in the Ruakura material for an equivalent growth period (4-28 weeks). As the within-set coefficients of variations were similar, viz. 3.2 per cent. and 2.8 per cent. in Bonnier's and Ruakura data respectively, the discrepancy was wholly due to a much greater between-set variability in Bonnier's material than in the Ruakura sample, viz. 22.6 per cent. and 9.5 per cent. respectively.

Bonnier also computed the variance for growth rate between the individuals of unrelated, single-born heifers in a sample reared the same way as the twins and found that this variance was almost exactly as high as the variance component between his sets of twins. Calculations on a similar sample of Ruakura, single-born heifers reared the same year as the twins showed that the variation between these animals on the one hand and that of the twins on the other hand were of the same order, e.g., the coefficients of variation were 10.4 per cent. and 9.5 per cent. respectively. Thus it seems that the variation in growth was consistently high at Wiad⁵ and consistently low at Ruakura. This may have been due to the following factors:—

(1) A greater genetic variability in the Wiad samples than in the Ruakura samples;

(2) difference in the methods of rearing which may have favoured the faster-growing animals at Wiad but the slower-growing animals at Ruakura.

On the available information it is not possible to decide which is the correct explanation.

The usefulness of monozygotic twins in growth trials, however, has been well established at both experimental stations and the above discussion merely serves to indicate how twin-efficiency values may vary from one population to another.

REFERENCES

- 1 HANCOCK, JOHN (1950): *N.Z. J. Sci. Tech.*, A 31 (5), 23-39.
- 2 HANCOCK, JOHN (1950): *N.Z. J. Sci. Tech.*, A 32 (4), 22-59.
- 3 BRODY, SAMUEL (1945): "Bioenergetics and Growth." Reinhold Publ. Corp., New York, U.S.A.
- 4 HANCOCK, JOHN (1950): Unpublished data.
- 5 BONNIER, GERT ; HANSSON, ARTUR and DURING, TROED (1946): *Kungl Lantbruks Akademiens Tidskr.* 85, 5, 455-67.

LAND-CRESS TAINT IN CREAM AND BUTTER

IV: THE RELATION OF THE ESSENTIAL OILS OF LAND CRESS (*Coronopus Didymus*) TO THE OCCURENCE OF LAND-CRESS TAINT IN CREAM AND BUTTER.

By F. H. McDOWALL, I. D. MORTON, and A. K. R. McDOWELL, The Dairy Research Institute (N.Z.), Palmerston North

(Received for publication, 23 August 1950)

Summary

Benzyl cyanide, which can be isolated from land cress by direct steam distillation, and benzyl isothiocyanate, which can be isolated indirectly, when added to cream for buttermaking, do not give true land-cress taint in the cream or butter. They are readily removed from the cream by steam distillation. When fed to cows they do not cause land-cress taint in the milk, or in cream from the milk. Feeding of cows with garden cress and garden nasturtiums, which yield benzyl isothiocyanate and benzyl cyanide under similar experimental conditions to land cress, does not cause land-cress taint in the milk. The indications are, therefore, that the benzyl mustard oil glucoside in land cress is not the source, or at any rate not the sole source, of the land-cress tainting substance in cream and butter.

INTRODUCTION

THE land-cress plant, when crushed in the mouth, has a sharp biting flavour. In this respect it resembles other mustard-oil-bearing plants such as garden cress, radishes and water cress. The flavour of land cress, however, is not so fresh and clean as that of the related plants.

Land-cress taint in butter, before the source of the taint had been traced, was formerly described as a "scorched" or "burnt" flavour. In Part II of this series¹ it has been shown that the mustard oil glucoside in land cress yields benzyl cyanide on direct steam distillation of the plant, and benzyl isothiocyanate on decomposition of the silver salt of the glucoside with sodium thiosulphate solution. During the distillation of the land-cress plant material for isolation of the oils as already reported,¹ the odour pervading the laboratories was described by butter graders as "somewhat similar" to land-cress taint in cream and butter. Other mustard-oil bearing plants are known to cause a taint in milk, cream and butter, e.g., water cress (*Nasturtium officinale*)², penny cress (*Thlaspe arvense*)³ and shepherd's purse (*Capsella bursa-pastoris*)⁴. It is then a facile inference that the mustard oil glucoside in land cress is responsible for the peculiar taint present in milk and cream from cows that have consumed the plant. The present paper surveys work designed to test the validity of this inference.

PROPERTIES OF BENZYL CYANIDE AND BENZYL ISOTHIOCYANATE

Benzyl cyanide is a liquid with an unpleasant odour and taste reminiscent of the land-cress and garden-cress plants, but with the "chemical" odour so characteristic of many benzene derivatives and without the sharp mustard-like taste of the land-cress plant. It has a boiling point of 234°C. at atmospheric pressure, and of 107°C. at 12 mm pressure, and is volatile in steam. Benzyl isothiocyanate is a liquid with a sharp odour reminiscent of radishes and of garden cress, and with little of the "chemical" flavour possessed by benzyl cyanide. It has a boiling point of 243°C. at atmospheric pressure, and of 121-125°C. at

12 mm pressure. It is also easily volatile in steam. Steam distillation was used at one stage in the silver-salt method of isolation of benzyl isothiocyanate from land cress¹, and the rate of steam distillation was such that the isothiocyanate was present in readily visible droplets in the distillate flowing from the condenser. In view of the difficulty experienced in removing land-cress taint from cream (see Part V of this Series), it would, at the outset, seem doubtful that the typical land-cress taint could be due directly to a substance so easily steam volatile as benzyl isothiocyanate, unless the isothiocyanate is adsorbed on to the protein-substances in the cream or is dissolved in the fat, and thereby is retained more tenaciously than in a watery suspension, or unless the isothiocyanate is slowly formed from a parent substance in the cream by the heat treatment.

EXPERIMENTAL

Flavour of Milk, Cream, and Butter containing added Benzyl cyanide and Benzyl isothiocyanate:

(a) *Benzyl cyanide*: Benzyl cyanide was added in varied proportions to milk and cream, and creams containing varied proportion of the substance were flash-pasteurized, were treated in the Vacreator vacuum-pasteurizer, and made into butter. The flavours of the contaminated products were sometimes described by the graders as "cressy", but with the qualifications "not true land cress" or "chemical" flavour. This applied also to the buttermaker's comments on the odour of the vapours evolved from the hot cream as it flowed through the flash-pasteurizers, or on that of the vapours rising from the warm Vacreator condenser-ejector tail-water from the Vacreator. The amount of benzyl cyanide detectable in cream varied considerably for different observers, and even for the same observer under different conditions, but was of the order of 1 part in 500,000 to 1 part in 10,000,000.

(b) *Benzyl isothiocyanate*: Cream containing added benzyl isothiocyanate, and the butter made from this cream, were described as having a "sharp radish odour" or a "chemical flavour reminiscent of garden cress", but not as having a "true land-cress flavour". Benzyl isothiocyanate in cream was not so readily evident to the senses as benzyl cyanide, but it could usually be detected in concentrations of 1 in 1,000,000 to 1 in 5,000,000.

Effect of Heat on Cream containing added Benzyl cyanide and Benzyl isothiocyanate:

Application of heat to milk or cream containing added benzyl cyanide or benzyl isothiocyanate did not increase the intensity of the off-flavours present, nor did it modify the nature of these off-flavours to the stage where they could be described as resembling true land-cress taint.

Steam Distillation of Cream containing Benzyl Cyanide or Benzyl Isothiocyanate:

The reports of failure to remove land-cress taint carried by small quantities of tainted cream into a large bulk of clean cream (see Paper I of this series) indicated that the substance responsible for the flavour was not readily steam-volatile, although the appearance of the typical taint in the vapours arising from a flash pasteurizer or a surface cooler, or in the Vacreator-condenser tail-water, showed that the tainting substance was at least slowly steam volatile. As stated above, both benzyl

cyanide and benzyl isothiocyanate are readily volatile in steam. Removal of these substances from cream, however, could conceivably be retarded by adsorption on to the milk proteins or by solution in the butterfat. These possibilities were checked in a number of experimental runs, both in the laboratory and in the butter factory. The following additives were used:—

- (1) Steam-distilled land-cress oil (mainly benzyl cyanide);
- (2) Synthetic benzyl cyanide;
- (3) Crude benzyl isothiocyanate, as extracted from cress by the silver-salt method;
- (4) Synthetic pure benzyl isothiocyanate;
- (5) Mixtures in varying proportions of benzyl cyanide and benzyl isothiocyanate.

These substances were added: (a) in alcoholic solution; (b) after emulsification with milk or with cream through a hand emulsifier or by means of a Turbo-mix; (c) after stirring with a small volume of cream for 2 hours; (d) after emulsification with warm cream and then standing with the bulk cream in the cold overnight; (e) after solution in liquid butterfat and emulsification by means of a hand emulsifier into skim milk before addition to the cream.

In all instances it was found that the added tainting material was removable by Vacreator vacuum-pasteurizer treatment. Where the concentration of added substance was high, double treatment in the Vacreator was sometimes necessary to effect complete removal, but these concentrations were always much higher than could possibly be derived from the small proportions of cress-tainted cream found in commercial practice to cause land-cress taint in butter.

Effect on Flavour of Milk, Cream and Butter of Feeding of Benzyl Cyanide and Benzyl Isothiocyanate to Cows:

If land-cress taint in cream and butter were due to the presence of benzyl cyanide or of benzyl isothiocyanate, it could be expected that ingestion of these substances by a cow would lead to presence of land-cress taint in the milk and cream. Five pounds of land cress contain approximately 1 g of benzyl isothiocyanate. This quantity of the plant, when fed to cows, usually causes strong cress taint in the milk and cream. In the feeding experiments described below, 2.0 g of the cyanide or isothiocyanate were taken, corresponding to 10-12 lb of land-cress plant.

The oils were mixed with 300 ml of milk for several minutes at 35°C., using a Turbo-mix, and were then added to 3.5 lb of mixed meals. The following proportions of benzyl isothiocyanate and benzyl cyanide were used:—

<i>Trial.</i>	<i>Benzyl Isothiocyanate.</i>	<i>Benzyl Cyanide.</i>
	(g)	(g)
A	2.0	0.0
B	1.5	0.5
C	1.0	1.0
D	0.5	1.5

The prepared meals were fed to four cows at 2.30 p.m. The cows ate the mixtures voluntarily. They were milked at 4 p.m. and at 5 a.m. The evening's and morning's creams were examined for the presence of land-cress taint before and after heating, and the creams were bulked, flash-pasteurized and churned. The cream and butter were comparatively free from off-flavour, and were quite free from the typical land-cress taint.

*Effect on Flavour of Milk, Cream, and Butter of Feeding of Garden-Cress (*Lepidium sativum*) to Cows:*

Garden cress, like land cress, contains a benzyl mustard oil glucoside, and yields benzyl cyanide on steam distillation, and benzyl isothiocyanate by the silver salt method¹. If the benzyl isothiocyanate glucoside in land-cress were the sole cause of the typical land-cress taint in cream, it could be expected that a similar flavour would be obtained in milk, cream and butter from cows consuming garden cress. The effect on the quality of the cream and butter of feeding garden cress to cows was tested in two separate series of Trials.

Trial A (December 1943): Four cows were forcibly fed at 11-12 a.m. on four successive days, with 3 lb, 5 lb, 6 lb and 7 lb of minced garden cress. They were milked at 3 p.m., 8 p.m. and 7 a.m. Cream was separated from the milk of each cow at each milking, and was graded both cold and after heating. The creams were then bulked, pasteurized in a small beater-type flash-pasteurizer, and were churned in a small Alfa churn. The creams had a definite off-flavour, variously described as "weedy", "mustardy", "sharp", and "resembling the flavour of benzyl isothiocyanate". The off-flavour, however, was not intensified by heat, and the heated creams and the butters from the pasteurized creams did not have the typical land-cress taint. This applied even after four consecutive days' feeding, whereas forced feeding of land cress on consecutive days has been found to result in a "build-up" of land-cress taint in the cream. Immediately following the failure to obtain land-cress taint in cream from the feeding of garden cress to cows, the same four cows were given 3 lb of land cress. The creams from all the cows, after heating, had a strong land-cress taint and the butter from the bulked cream had an intense typical land-cress taint.

Trial B (November 1946): The plant material from an area of garden cress available was found to yield 0.038 per cent of benzyl isothiocyanate by the quantitative method of extraction already described¹, compared with 0.045 per cent from a sample of land cress collected at the same time. Two cows were each forcibly fed with 4 lb of minced garden cress, and a further two were fed a similar quantity of land cress, two hours before the evening milking. The cream and butter from the cows fed garden cress was free from land-cress taint, while that from cows fed land cress showed the typical "burnt" land-cress flavour.

Effect on Flavour of Milk, Cream, and Butter of Feeding of Garden Nasturtiums to Cows:

The leaves and stalks of the garden nasturtium (*Tropaeolum majus*) contain a benzyl mustard oil glucoside (5, 6). Suitable quantities of crushed nasturtium plant were steam distilled, and similar quantities were extracted by the silver-salt method, as described in Part I of this series. It was confirmed that the nasturtium plant material available yielded benzyl cyanide and benzyl isothiocyanate under the conditions which were found applicable for land-cress plant material.

Quantities of 5 lb (and, later, 8 lb) of crushed nasturtium plant tissue were forcibly fed to each of four cows two hours before the night's milking. The cream and skim milk from each cow for both night's and the subsequent morning's milk were graded both cold and after heating. The night's cream before heating had a definite off-flavour described as somewhat astringent and bitter, and remotely reminiscent

of the plant. Morning's cream had a similar flavour, but in a milder form. The intensity of the off-flavour was not accentuated by heating the cream to boiling point under conditions which were known to develop true land-cress taint in cream from cows which had consumed land-cress plants. This flavour in the cream from cows fed with nasturtium tissue was quite dissimilar from land-cress taint. The skim milks were relatively free from off-flavour, both when cold and after heating.

The night's creams from the four cows were mixed, pasteurized in a small beater-type flash pasteurizer, cooled over a corrugated cylindrical cooler, and were churned after holding overnight. The butters were examined at the Dairy Research Institute and by the Department of Agriculture Graders at Wellington and Auckland. They had a "feedy" flavour, and some of them had an additional foreign flavour, which was described as "not typical of the smell of nasturtium leaves" and "quite distinct from land-cress taint".

CONCLUSION

From the results described above the following conclusions may be drawn:—

- (1) Benzyl cyanide and benzyl isothiocyanate, or a mixture of these two substances, when added to cream do not cause typical land-cress taint in either the cream or the butter.
- (2) The flavour of these substances in cream and in the resultant butter is not affected when the cream is heated.
- (3) Benzyl cyanide and benzyl isothiocyanate are removable from cream by steam distillation treatment in the Vacreator vacuum-pasteurizer.
- (4) Feeding of benzyl cyanide and benzyl isothiocyanate to cows did not cause land-cress taint in the milk yielded by them, or in the cream and butter obtained from this milk.
- (5) Feeding cows with garden cress, or with garden nasturtium, both of which contain a benzyl isothiocyanate glucoside, did not cause typical land-cress taint in milk, cream, or butter.

It seems clear, therefore, that the taint in milk and cream from cows consuming land cress is not due primarily to the presence of the mustard oil glucoside in the land-cress plant, although the possibility that this glucoside plays a part, along with some other constituents of the tissues, in the formation of the land-cress taint is not excluded.

ACKNOWLEDGMENTS

The authors desire to express their thanks to Mr. J. A. Singleton and Mr. J. J. O'Dea for assistance in the gradings of the creams and in the manufacture and gradings of the butters; and to the Department of Agriculture Graders in Wellington and Auckland for assistance in the examination of the butters.

REFERENCES

- (1) McDOWALL, F. H., MORTON, I. D., and McDOWELL, A. K. R. (1947): *N.Z. J. Sci. Tech., A*, 28, 305.
- (2) DEMPSTER, W. (1937): *N.Z. Dep. Agr. Bull.* 139.
- (3) COMBS, W. B. and COULTER, S. T. (1937): *J. Dairy Sci.* 20, 458.
- (4) MARTIN, W. H., et al. (1938-40): *Kansas Agr. Expt. Sta. Biennial Rept.*, p. 86.
- (5) MORTON, I. D. (1945): Unpublished results.
- (6) GADAMER (1899): *Ber der deutsch. Chem. Ges.*, 32, 23, 35.

LAND-CRESS TAIN IN CREAM AND BUTTER

V. FLASH PASTEURIZATION AND VACREATOR VACUUM-PASTEURIZATION OF LAND CRESS CONTAMINATED* CREAM

By F. H. McDOWALL, A. K. R. McDOWELL, I. D. MORTON, J. A. SINGLETON and J. J. O'DEA, The Dairy Research Institute (N.Z.), Palmerston North

(Received for publication, 23 August, 1950)

Summary

A proportion of raw cress-contaminated cream when added to bulk cream after pasteurization does not cause typical land-cress taint in the butter from the mixed cream. This procedure should not be practised because it lowers the quality and the keeping quality of the butter.

Attempts to modify the normal design of the Vacreator vacuum-pasteurizer in order to eliminate cress taint from cream were unsuccessful.

The extent of production of true land-cress taint through the action of heat on cream with latent land-cress taint is a function both of time and temperature of heating. Heating at 160°F. for a long period "develops", or causes gradual development of, the taint, but the critical temperature for short period heating is within the range 180-190°F. It was not found possible to reduce the time of heating at 204°F. in the Vacreator to the stage where land-cress taint was not developed from the latent taint in the cream.

Land-cress-contaminated cream, if of good quality, can be pasteurized at 170° and 180°F. respectively in two Vacreators operated in series, without developing cress taint. This method has been successfully used in several commercial factories, but it can only be safely applied to cream of high quality, and even with this class of cream there is some danger to the keeping quality of the butter.

The critical temperature of pasteurization for development of cress taint in the flash-pasteurization of cream is somewhat lower than for Vacreator treatment, because the time of heating in flash-pasteurization is longer and the danger of local overheating is much greater.

Heating of cress-contaminated cream to boiling point with direct steam for 30 minutes appears to develop the taint to the stage at which it is removable by steam distillation in the Vacreator. This method is applicable when the cress-contaminated cream is present in small proportions, and when it can be segregated. The heated cream is cooled and is spread over the whole supply on the following day, prior to Vacreator treatment. Addition of 7 per cent. of heated good quality cream to normal cream before Vacreator treatment had little effect on the grade and keeping quality of the butter; but addition of 15 per cent. of heated cream had a significant effect.

INTRODUCTION

PASTEURIZATION of cream is an essential step in the commercial process of butter manufacture, for destruction both of enzymes, such as lipase, and of contaminant bacteria. The heat treatment also gives to the cream and butter a pleasant, nutty, cooked flavour; and the formation of sulphides from the milk proteins by the action of heat is reported to improve the keeping quality of the butter. Cream from cows which have eaten the foliage of land-cress (*Coronopus didymus*) usually, but not always^{1,2} develops a strong typical land-cress taint when heated, as in the normal flash-pasteurization or Vacreator vacuum-pasteurization processes common in New Zealand butter factory practice. This cream in the raw state is not free from foreign off-flavour; but the raw-cream taint is different in character from that developed in the cream on heating, and it is difficult to detect during the ordinary cream-grading examination on the commercial factory receiving-stage. While some

cream-graders have been successful in segregating tainted supplies by an examination of the cream in the cold, the majority have found it necessary to heat the cream, in order to develop the true land-cress taint, before they can detect the contamination with any certainty. Segregation of the cream, either by careful grading of the cold cream, or by grading of the heated cream before tipping, may prevent spread of the cress taint through the whole factory supply; but it still does not provide a satisfactory means of treating the segregated cream for buttermaking. The quantity of cress-tainted cream may be too small to justify the work involved in separate pasteurization and churning, and frequently the quantity is so small that it could not be handled in any of the commercial churns available in the factory. The factory manager must then decide whether the cream which he has succeeded in segregating shall be pasteurized separately and then mixed with a portion of the factory supply, thus endangering the grade of at least a portion of the whole day's output; whether it shall be coloured and returned to the supplier; whether it shall be jettisoned at the factory's expense; or whether some other system of treatment may be applied in an endeavour to suppress or remove the taint.

HANDLING OF CRESS-TAINTED CREAM IN THE FACTORY

Addition of a Small Proportion of Raw Cress-contaminated Cream to Pasteurized Cream.

The addition of even a small proportion of raw cream to pasteurized cream for the manufacture of butter is inadvisable, because pasteurization is essential—

- (a) as a protection to the health of the consumers of the butter;
- (b) as a safeguard against bacterial deterioration of the butter during storage;
- (c) as a means of preventing the development of rancidity in the butter through the presence of undestroyed lipase from the raw cream.

The taint in raw cream from cows that have consumed land-cress is both milder and different in character from the flavour of the cream after heating. It has been stated that raw cress-tainted cream, when added to a bulk supply of pasteurized cream, does not cause cress taint in the butter, but hitherto there has not been available any published experimental evidence to support this claim.

Experimental.

A bulk supply of cream free from cress taint was divided into three equal portions, and a smaller supply of cress-contaminated cream was divided into two equal portions. In order to avoid the confusing effects of possible loss of some cress-tainting substances in the steam distillation treatment applied in the Vacreator, the bulk creams were pasteurized by the flash method. The detailed treatment of the creams was as follows:

- Cream 1. Flash-pasteurized to 160°F. and 202°F. in two tandem flash-pasteurizers of the beater type;
- Cream 2. One half of the supply of cress-tainted cream added, and then mixed cream flash-pasteurized as for No. 1;
- Cream 3. Flash-pasteurized as for No. 1, and then one half of the supply of cress-tainted cream added in the raw state.

* In the present paper the terms "land-cress-contaminated" and "latent land-cress-tainted", are used to denote creams which have not been heated to develop the typical "burnt" land-cress taint.

The butters were graded soon after manufacture by three independent groups of graders, Panels A, B and C, and again by Panels A and B after storage for 4 and 8 months respectively. The results, given in detail in Table I, show clearly that (a) the addition of cress-contaminated cream in the raw state to the bulk pasteurized cream did not cause the appearance of land-cress taint in the butter, and (b) the strong cress taint in the butters from Churning 2, for which the cress-tainted cream was pasteurized along with the bulk supply, was due to the effect of the heat on the latent cress taint in the cream.

TABLE I. COMPARISON OF EFFECTS OF HEATED AND RAW CRESS-TAINTED CREAMS ADDED TO A BULK CREAM, ON THE FLAVOUR AND KEEPING QUALITY OF BUTTER

Age of Butter.	Butter Graded by	Churning No. 1. No Cress Cream added.		Proportion of Cress Cream added. (%)	Churning No. 2. Cress Cream added before Pasteurization.		Churning No. 3. Raw Cress Cream added to Pasteurized Cream.	
		Grade Score.	Remarks.		Grade Score.	Remarks.	Grade Score.	Remarks.
Fresh	Panel A	91	—	10	90	Strong cress	90	Stale cream flavour
"	Panel B	90	—	"	89	Strong cress	88	Unsound
"	Panel C	91.5	—	"	88	Strong cress	87.5	Unclean "cowy" flavour
4 Months	Panels A and B	90	Feedy, no cress	"	89	Strong cress	88	Sour and rancid
8 Months	Panels A and B	89.5		"	88	Strong cress	87	
Fresh	Panel A	92	—	7.5	91	Cress	92	—
"	Panel B	92	—	"	89	Intense cress	90.5	—
"	Panel C	90.4	—	"	87	Strong cress	89	—
4 Months	Panels A and B	91	—	"	89	Strong cress	89	"Feedy" and cress
8 Months	Panels A and B	90	—	"	88	Intense cress	89	—
Fresh	Panel A	91.5	Cow	9	88	Strong cress	91.5	Strong off-flavour
"	Panel B	92	—	"	88	Intense cress	91	—
"	Panel C	91.6	—	"	88	Strong cress	91.5	—
4 Months	Panels A and B	90.5	—	"	88	Strong cress	90	Inclined rancid
8 Months	Panels A and B	90	—	"	88	Intense cress	89	no cress Rancid

The grade scores for the fresh butters from creams containing raw cress-tainted cream were fairly consistently lower than the scores for the control butter. Their relationship to the grade scores for the cress-tainted butters (Churning No. 2) varied with the intensity of the cress taint developed in these latter butters and with the general quality of the raw cream added. The remarks on "unsound" and "rancid" off-flavours in the butters containing raw cream lend emphasis to the danger of using this method of disposal of cress-tainted cream, although estimation of the acid values in the butterfats from the butters after 4 months' storage did not show evidence of extensive hydrolysis. The average acid values for the butterfats from Churnings Nos. 1, 2 and 3, were 0.16, 0.17 and 0.20. The difference was thus insignificant.

Attempts to remove Land-cress Taint from Cream by Normal and modified Treatment in the Vacreator Vacuum-pasteurizer

Experience in commercial factories has shown that the normal degree of deodorization applied in the M-type Vacreator will not remove land-cress taint from cream. Although the ejector-condenser tail-water has a strong cress odour, the high temperature to which the cream is heated accentuates the cress taint in the Vacreator-treated cream in the same way as it does with flash-pasteurized cream (see Table I). It was evident, therefore, that some variation from the normal system of cream treatment would be necessary before the Vacreator could be successfully used for the elimination of land-cress taint. Extensive trials of a wide variety of conditions of treatment, and of modifications of the Vacreator equipment, were made at the Dairy Research Institute experimental factory, using a "Baby" model Vacreator, and in a commercial factory using a standard M-type machine.

Experimental.

A bulk supply of cress-tainted cream was accumulated in a neutralizing-vat. During treatment of this cream in the Vacreator, the conditions of operating the machine were varied. When sufficient time had elapsed following the adjustment of the machine, to allow the full effect (if any) of the adjustment to show in the cream issuing from the fat-extractor-pump outlet, a 7-lb. sample of the treated cream was collected in a small can and was cooled in chill water. The conditions of treatment were then varied and the process of sample collection was repeated. In this way upwards of twelve samples of cream corresponding to different systems of cream treatment could be obtained with use of one vat of raw cream. The creams were held in the chill-room overnight, they were then churned in a small Alfa rotary churn, and were worked in a hand worker of the type commonly used in farm buttermaking. The butters were graded at the Institute or at the commercial factory, and duplicate samples were graded by Department of Agriculture graders at the Auckland Grading-stores.

The following are the most important of the modifications tried :

- (a) Elongation of the pasteurizer section of the Vacreator to double its normal height, with the object of prolonging the period of contact of the steam with the cream at the high pasteurizing temperature.
- (b) Insertion, below the equilibrium valve, of an annular retarder, 24 in. high, fitted with baffles compelling the cream to traverse up and down over this height and change its direction four times before passing to the uptake pipe, thus giving a more complete mixing of the steam with the cream, and a longer time of contact.

(c) In addition to the above annular retarder, attachment of a 6 ft. long horizontal 5-in. pipe between the pasteurizer section and the retarder, with Archimedean-screw insert closely fitting to the inside of the pipe (the pasteurizer section of the first leg of the machine was attached to the second separating-chamber, thus leaving space for insertion of the pipe). The object of these modifications was to increase still further the time and intimacy of contact of the steam with the cream.

(d) Addition of an 8 ft. long section on top of the intermediate float tank, and withdrawal of the cream from the first separating-chamber by means of an auxiliary pump, and passing it down the "spray tower" in fine droplets against a current of steam. An ejector-condenser of enlarged capacity was installed to cope with the larger amount of steam passed through. It was connected by means of a Y-branched gooseneck to both the first separating-chamber and the spray tower, which thus were operated at the same reduced pressure.

(e) Insertion of a second annular retarder in the uptake pipe of the second unit, and injection, via the infuser connection, of as much steam as could be handled by the second unit condenser.

(f) Removal of the equilibrium valve and of the intermediate float tank valve, in order to raise the temperature of steam distillation to the highest value obtainable (the closed-head attachment for the Vacreator⁴ was not then available).

(g) Reducing the flow of cream through the M-type machine to the practical minimum of 300 gal. per hour, with or without use of some or all of the above described attachments, and with injection of steam to give an overall intensity of treatment as high as 1800 B.T.U. per pound of cream.

(h) Variation of the vacuum applied in both units over the whole practical range, and variation of the pasteurization temperature over the range 180°F.-205°F.

The results with these modifications of the Vacreator vacuum-pasteurizer treatment were not encouraging. There was ample evidence that some cress-tainting substance was being removed, since the vapours from the ejector-condenser tail-water were strongly tainted, but the treated creams and butters still showed strong cress taint. It was concluded that consistent complete removal of land-cress taint from cream by treatment in the commercial Vacreator could not be obtained through increase in the intensity of steam distillation applied. The most promising modification tried at the Institute in 1939, and in the commercial factory in 1940, was reduction in the temperature of pasteurization. Since, as shown in Table I, raw cress-tainted cream does not cause typical land-cress taint in butter, while cream flash-pasteurized at 200°F. does show this taint, there must be an intermediate or transition temperature at which appearance of the typical land-cress taint in the cream commences.

*Relation of Temperature of Pasteurization of Land-cress-tainted Cream
to Intensity of Land-cress Taint in Cream and Butter*

Laboratory Trials.

Creams from cows feeding on a cress-infested area were heated in test-tubes for 5 minutes, 10 minutes and 30 minutes, at 150°F., 160°F., 170°F., 180°F. and 190°F. (because of the period required for raising and lowering the temperatures, the relative times of maintenance of the

creams at the final temperatures were somewhat out of proportion with the total amount of heating applied). The cooled creams were graded according to their intensity of cress-taint on an arbitrary scale of 0 to 10. The results showed that the intensity of cress taint developed was a function both of time and temperature of heating, and that a long period of holding at 160°F. could develop the cress taint from the latent to the observable state. The critical temperature for rapid increase in the intensity of cress flavour was found to be over the range 170°-185°F.

In order to obtain a short period of heating at the final temperature, a laboratory model vacuum-pasteurizer was constructed in glass. It permitted almost instantaneous heating of the cream to the final temperature by means of injected steam, and immediate cooling to a much lower temperature by flashing into a region of lower pressure through an ordinary glass tap. When latent-cress-tainted cream was passed into the apparatus under these conditions, accentuation of the intensity of cressy off-flavour became marked at 183°-185°F., and momentary heating in this apparatus to 204°F. gave a very definite increase in the intensity of cress taint.

Factory Trials using Flash-pasteurization.

A quantity (25-50 lb.) of cream with latent land-cress taint was added to 1,200 lb. of good quality cream, and the bulk was divided into three portions. Two of these portions were treated at low temperatures in tandem flash pasteurizers, and the third portion was treated in the same pasteurizer at the usual pasteurizing temperatures, viz. 160°F. and 200°F. The creams were churned in an internal-worker churn, and the butters were graded by three groups of graders. Some of the

TABLE II. RELATION OF TEMPERATURE OF FLASH PASTEURIZATION OF CREAMS WITH LATENT LAND-CRESS TAIN TO INTENSITY OF CRESS TAIN IN THE BUTTER

Date.	Temperatures of Pasteurization. (°F.)	Grading* of Butter.	Number of Bacteria per gram in	
			Cream after Pasteurization.	Butter.
16.10.45	150,170	91 Suggestion of raw-cream flavour. No cress.	1,024,000	236,000
	160,185	88.8 Strong cress	13,000	3,500
	170,200	88 Very strong cress	2,700	3,800
30.10.45	150,170	91.5 No cress	4,000,000	117,000
	170,170	91.8 No cress preferable to No. 1	474,000	487,000
	160,200	89 Intense cress	270	3,780

* Average of 3 separate gradings.

results are given in Table II. They confirm the conclusion, reached from the laboratory investigation, that the critical temperature is over the range 170°-185°F.

When latent-cress-tainted cream was preheated in tandem flash pasteurizers at 160°F. and 170°F. respectively, and was then double treated at 170°F. in a "Baby" Vacreator, it yielded a butter with only a suggestion of cress taint; whereas flash-pasteurization of a portion of the same cream supply at 160°F. and 200°F., or Vacreator treatment at 200°F., gave butters with a definite cress taint.

*Effect of Low Temperature Flash-pasteurization of Cream on the
Flavour and Keeping Quality of Butter*

The New Zealand system of flash pasteurization of cream in tandem machines up to a final temperature of 200°-204°F. has given butters of consistently sound keeping quality. While low temperature pasteurization of a small quantity of segregated latent-cress-tainted cream before addition to the main supply is not likely to be seriously harmful to the quality of the butter, a system of low temperature pasteurization of all the cream received could possibly lead to a general lowering of the quality of the butter produced. The magnitude of the effect on keeping quality would depend on the general quality of the cream supply, independent of the volume of cress tainted cream received. The comparisons described in Table III were made at the Dairy Research Institute experimental factory with creams of good basic quality.

TABLE III. EFFECT OF LOW TEMPERATURE FLASH PASTEURIZATION OF GOOD QUALITY CREAM, FREE FROM LATENT CRESS TAINT, ON THE QUALITY AND KEEPING QUALITY OF BUTTER

Butter graded by	Age of Butter.	Grade Scores for Temperatures of Flash Pasteurization (°F.)			Differences in Grade due to Pastn. at °F	
		150,170	160,180	160,200	150°,170°F	160°,180°F
Panel A	Fresh	92.67	92.67	92.67	±0	±0
Panel B	"	92.0	92.5	93.0	-1.0	-0.5
Panel C	"	92.0	92.13	92.7	-0.7	-0.37
Average of 3 gradings	"	92.22	92.43	92.79	-0.57	-0.36
Panels A & B	4 Months	91.83	92.25	92.58	-0.75	-0.33
Panels A & B	8 Months	91.83	92.17	92.16	-0.33	+0.01
Average Bacterial Counts in Pasteurized Creams and Butters	Creams	400,000	7,000	700	—	—
	Butter					
	Fresh	90,000	5,000	3,300	—	—
	8 Months	2,500	3,000	3,300	—	—

There was consistently a lowering of the grade due to pasteurization at the low temperatures, but the magnitude of the lowering was surprisingly small. The deterioration was not caused by extensive lipase action in the butters from creams pasteurized at the low temperatures, since the acid values of the butterfats, after 8 months' storage, were uniformly low. The bacterial counts for the butters from creams pasteurized at 150° and 170°F. were significantly high, but those for the butters from creams pasteurized at 160° and 180°F. were not very different from those for the butters from creams pasteurized at 200°F. The differences in bacterial count were less evident in the butters after 8 months' storage.

Factory Trials, with Vacreator Treatment at 175°F., 200°F. and 212°F.

Bulk cream containing some latent-cress-tainted cream was divided into three portions which were pasteurized in a "Baby" Vacreator at 175°F., 200°F. and 212°F. respectively. The butters were graded when fresh by three independent groups of graders, as before, and after 4 months' and 8 months' storage. The results are given in Table IV.

TABLE IV. COMPARISON OF LOW TEMPERATURE AND HIGH TEMPERATURE VACREATOR VACUUM-PASTEURIZATION OF CREAMS WITH LATENT CRESS TAINT

Age of Butter when Graded.	Grade Score of Butter for Pasteurization Temperature of					
	175°F.		200°F.		212°F.	
Fresh	92.3	No cress	91.4	Cress	91.0	Cress
4 Months	92.0	No cress	90.5	Strong cress	89.0	Strong cress
8 Months	91.0	No cress	90.0	Cress	90.0	Definite cress
Fresh	91.5	No cress	91.0	Slight cress	90	Cress
4 Months	92.0	No cress	90.75	Strong cress	90	Intense cress
8 Months	91.0	No cress	90.5	Cress	90.5	Cress

They confirm that low temperature pasteurization of cream in the Vacreator, like similar treatment in the tandem flash-pasteurizers, inhibits the development of cress taint in the cream and its appearance in the butter; and they confirm results obtained earlier by Mr. R. A. Harvey, then Manager of the Tauranga Co-op. Dairy Co., that cream with latent cress-taint could be successfully handled, under commercial conditions of Vacreator operation, by keeping the pasteurization temperature below 180°F.

Effect of Low Temperature Vacreator Treatment of Cream on the Quality of Butter.

The effect of low temperature of treatment in the Vacreator on the grade and general keeping quality of butter cannot be estimated satisfactorily with latent-cress-tainted cream, because the effect of high temperatures in increasing the intensity of cress taint confuses the issue by altering the grade score of the control butter. It can be expected, also, that the influence of temperature of pasteurization on butter quality will vary with the rate of flow, which influences the time of holding at high temperature in the Vacreator. High rates of flow at low temperatures of pasteurization will increase the tendency to unsatisfactory destruction of enzymes and contaminant bacteria. The effect of low temperature Vacreator vacuum-pasteurization of cream on butter quality, therefore, can be expected to vary with the quality of the raw cream.

Trials of the effect of low temperature pasteurization of untainted cream were made both at the Dairy Research Institute and at a commercial factory.

Dairy Research Institute Comparisons: A supply of good quality cream was divided into three portions. These were treated in a "Baby" model Vacreator at a flow of 100-120 gal. per hour, and with pasteurization temperatures of 170°F., 180°F. and 200°F. respectively. The butters were graded soon after manufacture by three independent groups of graders, and after 4 and 8 months' storage. The average results for four comparisons are given in Table V. Results for a similar series of comparisons, with pasteurization temperatures (a) 180°F.; (b) double treatment at 180°F. (cream after the first treatment delivered back to the neutralizing-vat, at 130°F., and then when first treatment complete, whole of cream retreated at 180°F.), and (c) 200°F. These results are given in Table VI.

While the grading results for the fresh butters were not consistent as between the three groups of graders, the figures taken as a whole indicate that there was some loss in quality and keeping quality of

butter through use of low temperature pasteurization in the Vacreator, but the reduction in grade due to the low temperature of treatment was almost certainly smaller than the loss in grade score caused by heating cream with latent land-cress-taint to a high temperature. The destruction of bacteria in the cream heated once at 170°F. (Table V) was far from satisfactory, but raising the temperature to 180°F. corrected this fault. The fat acidity values were scarcely affected by the low temperature of cream treatment in the Vacreator.

TABLE V. RELATION OF TEMPERATURE OF PASTEURIZATION OF GOOD QUALITY CREAM IN VACREATOR VACUUM-PASTEURIZER TO QUALITY OF BUTTER. (TEMPERATURES 170°F., 180°F. AND 200°F.)

(Results represent averages of results for four comparisons)

Butters graded by	Age of Butter.	Average Grade Scores of Butters from Creams Vacreated at			Differences in Grade Score due to Vacreator treatment at	
		170°F.	180°F.	200°F.	170°F.	180°F.
Panel A	Fresh	92.92	93.21	93.42	-0.50	-0.21
Panel B	"	92.83	93.17	93.46	-0.63	-0.29
Panel C	"	93.05	93.12	92.95	+0.10	+0.17
Average	"	92.93	93.17	93.28	-0.35	-0.11
Panels A & B	4 Months	91.81	92.18	92.57	-0.76	-0.39
Panels A & B	8 Months	91.25	91.55	91.83	-0.58	-0.28
Bacterial Counts	Fresh					
	pasteurized Cream	1,080,000	22,000	20,000	—	—
	Fresh Butter	101,000	50,000	24,000	—	—
	Butter at 8 Months	2,600	3,000	2,500	—	—
Fat Acidity	8 Months	0.21	0.15	0.12	—	—

TABLE VI. VACREATOR VACUUM-PASTEURIZATION OF GOOD QUALITY CREAM AT 180°F., COMPARED WITH DOUBLE VACREATOR TREATMENT AT 180°F., AND SINGLE VACREATOR TREATMENT AT 200°F. (AVERAGE OF FIVE COMPARISONS)

Butter graded by	Age of Butter.	Average Grade Score of Butters from Cream Vacreator-treated at			Difference in Grade Score due to Vacreator Treatment at	
		180°F.	180,180°F.	200°F.	180°F.	180,180°F.
Panel A	Fresh	91.75	91.25	91.94	-0.19	-0.19
Panel B	"	91.75	91.94	92.50	-0.75	-0.56
Panel C	"	92.63	92.30	92.21	+0.42	+0.09
Average	"	92.04	92.00	92.22	-0.18	-0.22
Panels A & B	4 Months	90.81	91.25	91.62	-0.81	-0.37
Panels A & B	8 Months	90.12	90.06	90.38	-0.26	-0.32
Bacterial Counts	Fresh	3,980	4,200	19,300	—	—
	8 Months	13,000	40,000	19,000	—	—
Fat Acidities	8 Months	0.18	0.19	0.19	—	—

Commercial Factory Comparisons, using Good Quality Cream: These comparisons were made at the butter factory of the Tauranga Co-op. Dairy Co. The equipment in use for cream treatment consisted of two M-type Vacreators, coupled in tandem so that the cream in passing through the system was given a double treatment. The temperature reached in the first machine was 170°F. Over a consecutive 10-day period the whole cream supply was treated, in the final machine, at 200°F. and 180°F. on alternative days. The rate of cream flow was 800 gal. per hour. Boxes of butter from three of the churnings each day were set aside for special gradings at the Auckland grading store, and other boxes from these same churnings were held in storage at 14°F. for 4 months and 8 months. There were thus available for examination 15 boxes of butter from cream treated at each temperature, for each grading period. The butters were graded "blind" by 10 individual graders, and the results were averaged. The average grading results, and the average bacterial counts, are given in Table VII.

TABLE VII. COMPARISON OF GRADINGS, BACTERIAL COUNTS AND FAT ACIDITIES OF BUTTERS FROM CREAMS VACREATOR-TREATED AT 180°F. AND AT 200°F. ON CONSECUTIVE DAYS IN A COMMERCIAL FACTORY (5 DAYS AT EACH TEMPERATURE, BOXES OF BUTTER FROM 3 CHURNINGS ON EACH DAY)

Age of Butter at Grading.	Average Grade Scores of Butters from Cream treated at		Difference in Favour of Treatment at 200°F.	
	180°F.	200°F.		
Fresh	92.2	92.6	+0.4	
4 Months	91.3	91.6	+0.3	
8 Months	89.4	90.2	+0.8	
Further 11 days at room temp.	86	88.2	+2.2	
	Bacterial Counts on Butters from Creams Treated at		Fat Acidities of Butterfats from Butters Treated at	
	180°F.	200°F.	180°F.	200°F.
Fresh	124,000/g.	27,000/g.	0.20	0.20
8 Months	12,300/g.	11,600/g.	0.20	0.20

The creams received at the factory over the ten days of treatment were of fairly uniform quality. On the days when the pasteurization temperature was 180°F., 69 per cent. of the cream received was of finest quality, and on the other five days the proportion was 63 per cent. The butters for each group were of uniformly low copper and iron contents. While the creams used in the trial were not of identical quality from day to day, the comparison may be accepted as a reasonably valid indication of the effect of the low temperature pasteurization when good quality cream is being received. The butters obtained from the cream treated at the lower temperatures were consistently of slightly inferior quality immediately after manufacture, and had inferior keeping quality in comparison with the butters receiving normal pasteurization treatment at 200°F. The more rapid deterioration of the low-temperature butters when held at room temperature after storage is an indication that the margin of safety with these butters was smaller. The differences in quality and keeping quality could be expected to be more distinct with use of poor quality cream. This lower margin of safety with butters from creams treated at a low temperature has been evident at times

in the examination, and in routine keeping quality trials, of butters from commercial factories using the low temperature pasteurization system for suppression of land-cress taint. The method should be used only with good quality cream and only when other methods of handling the cress-tainted cream are not available. Indeed, butter with cress-taint but of good keeping quality is preferable to butter free from cress-taint but of doubtful keeping quality. Where low temperature pasteurization is adopted as the best expedient, it is advisable to *segregate all cream suspected of being cress-contaminated, and to restrict the low temperature treatment to this cream.* Unfortunately, however, because of the difficulty of detecting latent cress-taint, the necessary accurate segregation is difficult to accomplish, although heating of the cream before grading, as previously described¹, is of assistance in this respect.

Effect of Successive Low Temperature Vacreator Treatments of Latent Land-cress Tainted Cream and of Vacreator Treatment at Low Temperatures prior to Treatment at High Temperatures.

If the substance transformed into typical land-cress taint by heat were steam-volatile at a low temperature it should be removable by continued low temperature Vacreator treatment.

A sample of bulk cream sufficient for three churnings, and containing some "cressy" cream, was treated in the Institute "Baby" model Vacreator at 170°F. After one treatment at this temperature a proportion sufficient for one churning was withdrawn, and a sample was taken for flash pasteurization in a small beater-type machine at 190°F. and churning in a small Alfa churn. The remainder was treated in the Vacreator again at 170°F., sufficient cream for a second churning was

TABLE VIII. EFFECT OF LOW TEMPERATURE VACREATOR TREATMENT AT HIGH INTENSITY PRIOR TO HIGH TEMPERATURE TREATMENT ON THE INTENSITY OF CRESS TAIN IN BUTTERS FROM LATENT "CRESSY" CREAM

Butters graded by	Age of Butter.	Grade Score and Remarks for Butters Vacreator-treated at			
		175°F.	175° and then 200°F.	200°F.	
Panel A	Fresh	91 Slight cress	89 Intense cress	88 Intense cress	
Panel B	"	92 Slight cress	91 Strong cress	90 Strong cress	
Panel C	"	92.2 Slight cress	90.4 Strong cress	89.4 Strong cress	
Panels A and B	4 Months	91.5 No cress	91 Intense cress	89 Very strong cress	
Panels A and B	8 Months	91 No cress	90 Strong cress	88 Very strong cress	
Panel A	Fresh	92.5 No cress	91 Definite cress	91 Definite cress	
Panel B	"	92 No cress	90.25 Strong cress	90.5 Cress	
Panel C	"	92.5 No cress	90.8 Strong cress	90.7 Cress	
Panels A and B	4 Months	91.5 No cress	90 Strong cress	89 Very strong cress	
Panels A and B	8 Months	91 No cress	89 Strong cress	88 Very strong cress	

taken, and a small sample was withdrawn for small scale flash pasteurization and churning. The remainder was treated a third time at 170°F. and a small sample was withdrawn for small scale pasteurization and churning. The repeated treatment at 170°F. had a slight tendency to develop the latent cress taint into typical cress taint, and it had a significant positive effect on the intensity of cress taint developed by flash pasteurization of the small samples withdrawn. There was, therefore, no evidence of removal of the latent cress-tainting substance by the low-temperature Vacreator treatment. The finding was confirmed by several comparisons of low temperature Vacreator treatment at the maximum intensity, followed by high temperature Vacreator treatment, compared with straight high temperature treatment (see Table VIII). The prior treatment at 175°F. made no significant difference in the intensity of the cress taint in the butter after a further treatment of the cream at 200°F. The substance responsible for latent cress taint in cream and butter thus appeared to be non-steam-volatile.

Effect of Heating in Vacreator for Minimum Time.

Under ordinary conditions of Vacreator vacuum-pasteurization treatment the temperature of the cream in the first separating-chamber is above 180°F. The conditions in the separating-chamber, therefore, are such as to develop the taint in cream with latent cress taint. By raising the vacuum applied in the first separating-chamber to above 15 inches, the temperature of the cream as it issues past the equilibrium valve can be reduced to below the critical temperature for short period heating. This restricts the period of high temperature treatment to that required for passage of the cream through the lower section of the pasteurizer unit.

Bulk cream with latent cress taint was treated in the Vacreator in three equal portions as follows :

1. at 175°F.
2. at 200°F. with highest possible vacuum (22 in.) in 1st unit.
3. at 210°F. with highest possible vacuum (22 in.) in 1st unit.

The results shown in Table IX are typical. It is evident that even momentary heating of the cream is sufficient to develop the latent cress taint into normal cress taint.

TABLE IX. EFFECT OF HIGH TEMPERATURE TREATMENT IN THE VACREATOR FOR THE MINIMUM TIME (I.E. WITH HIGH VACUUM ON 1ST UNIT) ON THE DEVELOPMENT OF CRESS TAIN IN CREAM

Grading.	Grade Scores for Butter Vacreator-treated at		
	175°F.	200°F.	210°F.
Average of three gradings on fresh butter	92.3 No cress	91.4 Cress	91.4 Cress
4 Months	92 No cress	90 Strong cress	89 Strong cress
8 Months	91 No cress	90 Strong cress	90 Strong cress

Reaction Time in Development of Cress Taint by Heat.

While the reaction time for the commencement of development of cress taint by the action of heat on cream with latent cress taint is very short, as shown in the preceding sections, the possibility still remains that completion of the reaction may extend over a considerable period.

This would explain why cress taint is present in the Vacreator tail-water vapours, and, at the same time, there is no indication of any lessening of cress taint in the cream being treated, i.e., the cress taint may be forming as quickly as it is removed. Experiments on the treatment of "cressy" cream with chlorine (to be described in Part VI of this Series) have confirmed that the action induced by heat on the cress-tainted cream is not immediately completed. From this finding the following questions arise: (a) can the reaction be carried to completion by high temperature treatment for a reasonable time; (b) after completion of the reaction, can the cress taint be completely removed from the cream.

Experimental.

Preheating of cream with latent cress taint to flash-pasteurization temperature and delivering to the Vacreator through a long pipe giving a holding time of 2 min. was found inadequate. Even after holding the cream at flash-pasteurizing temperature for 20 min., intense Vacreator treatment did not remove all the cress taint. The cream with latent cress taint, therefore, was heated separately in a cream-can by passage of a current of direct steam for 30 min. It was then added to a bulk supply of nine times its volume of good quality flash-pasteurized cream, and the mixed cream was divided into three portions, which were treated as follows:

- (1) Pumped directly over the coolers.
- (2) Treated in the Vacreator once at 200°-204°F. at maximum intensity of steam distillation.
- (3) Treated in the Vacreator twice at 200°-204°F. at maximum intensity.

The average results for gradings of the butters from several replicate comparisons are given in Table X. The prolonged treatment of the cress-tainted cream prior to Vacreator treatment reduced the intensity of the cress taint in the final butter, but elimination of the taint in the Vacreator was not complete.

TABLE X. EFFECT OF VACREATOR TREATMENT ON FLASH-PASTEURIZED CREAM CONTAINING SOME "CRESSY" CREAM WHICH HAS BEEN HEATED TO BOILING POINT FOR 30 MINUTES

Grading.	Age of Butter.	Grade Score of Butter from Creams.		
		(1) Not Vacreator-treated.	(2) Vacreator-treated once.	(3) Vacreator-treated twice.
Panel A	Fresh	89.75	91.13 Cress	91.15 Slight cress
"	"	89.25	90.31 "	90.51 "
Panel B	"	89.5	90.62 "	91.52 "
Panel C	4 Months	88.0	90 "	90.52 "

The difference between the gradings cited in Table X cannot be attributed wholly to removal of cress taint, but was due in part to removal of off-flavours other than cress, i.e., the normal improvement in butter quality resulting from Vacreator treatment. The experiment was therefore repeated using Vacreator treatment for the control cream as follows:

- Churning 1. Bulk cream free from latent cress taint, treated in the Vacreator at 200°F, and with maximum intensity of treatment.

Churning 2. Bulk cream plus 6-12 per cent. of cress cream, treated in the Vacreator under same operating conditions as for Churning 1.

Churning 3. Bulk cream plus the same volume of cress cream as for Churning 2, but cress cream boiled with current of steam for 30 minutes.

The average grading results for several replicate comparisons are given in Table XI. There was definite evidence in the grade scores

TABLE XI. EFFECT OF VACREATOR TREATMENT ON CREAM CONTAINING CRESS CONTAMINATED CREAM WHICH HAS BEEN HEATED TO BOILING POINT FOR 30 MINUTES

Grading.	Age of Butter.	Grade Score of Butter from.			Difference in Grade Score due to Presence of Cress Cream.	
		Churning 1.	Churning 2.	Churning 3.	Churning 2.	Churning 3.
Panel A	Fresh	92.25	90.91	91.50	-1.34	-0.75
Panel B	"	92.25	90.61	91.37	-1.64	-0.88
Panel C	"	92.37	90.47	91.27	-1.90	-1.10
Average	"	92.29	90.66	91.38	-1.57	-0.91
Wgtn.	4 Months	91.87	90.81	91.37	-1.06	-0.50
Wgtn.	8 Months	91.25	90.1	90.87	-1.15	-0.38

and in the remarks on intensity of cress taint that Vacreator treatment was effecting a progressive improvement in the quality of the cream through removal of a volatile cress-tainting substance. Some of the graders were unable to find cress taint in some of the butters from Churning 3. The proportion of cress-contaminated cream added varied from 6 to 12 per cent. of the total volume for each churning. It was concluded that a small proportion of cress-contaminated cream, segregated on the factory receiving-stage, could be successfully handled, without causing cress taint in the butter, if it were steamed for 30 min., cooled, held over until the following day, and were then spread evenly over the whole supply. This method has been used in one New Zealand factory throughout a dairying season, with only very occasional occurrences of cress taint in the butter (and these occurrences may have been due to some cress-contaminated cream escaping the notice of the cream grader). Use of this method for handling a large proportion of the cream supply would not be practicable.

Effect of Adding a Proportion of Cream Heated with Direct Steam for 30 Minutes on the Quality of Butter

If the system detailed in the preceding section, viz., heating cream to boiling point for 30 min. prior to intense Vacreator treatment, should prove generally successful in commercial practice, some evidence is required of the effect of the treatment on butter quality, apart from its effect on the intensity of cress taint. Comparisons were therefore made with the addition of a proportion of "boiled-up" good quality cream to normal cream before Vacreator vacuum-pasteurization.

Experimental.

A bulk sample of cream was divided into three portions. Quantities of cream equivalent to 7 and 15 per cent. were withdrawn from portions

2 and 3 respectively, and were heated with a current of direct steam for 30 min., and were added to the remainder of the respective bulk creams immediately before Vacreator treatment. Treatment conditions for the three lots of cream were then maintained normal. The grading results, given in Table XII, show that the effect of the addition of 7 per cent. of heated cream on the grade of the fresh and stored butters was of minor significance. The effect of adding 15 per cent. of heated cream was still small, but it was clearly and consistently evident in the stored butter. Addition of 7 per cent. of boiled-up cress-contaminated cream is probably the maximum which could be successfully handled under normal commercial conditions of Vacreator operation to give complete removal of the "developed" cress taint. The results

TABLE XII. EFFECT OF PREHEATING 7 PER CENT. AND 15 PER CENT. OF CREAM TO BOILING POINT FOR 30 MINUTES, PRIOR TO VACREATOR TREATMENT, ON THE QUALITY AND KEEPING QUALITY OF BUTTER (AVERAGE OF 4 COMPARISONS)

Grading.	Age of Butter.	Grade Score of Butter from Cream.			Differences in Grade due to Addition of	
		Containing no treated cream.	Containing 7% treated cream.	Containing 15% treated cream.	7% heated cream.	15% heated cream.
Panel A	Fresh	93.25	93	92.63	-0.25	-0.62
Panel B	"	93.25	93.25	93.25	±0	±0
Panel C	"	92.30	92.68	92.53	+0.38	+0.23
	Average	92.93	92.98	92.80	+0.05	-0.13
Panels A and B	4 Months	92.88	92.81	92.38	-0.07	-0.50
Panels A and B	8 Months	92.31	92.19	91.75	-0.12	-0.56

in Table XII show, therefore, that when the boiling-up treatment is found effective as a means of eliminating land cress taint, it can be safely used with 7 per cent. of the supply without serious prejudice to the grade and keeping quality of the butter.

Effect of Repeated High Temperature Treatment of Cress-Contaminated Cream in the Vacreator on Intensity of Cress Taint in the Butter.

Since the rate of production of cress taint is increased by rise in temperature, and since extent of development of taint appears to be a function of time of heating, it seemed probable that repeated Vacreator treatment at high temperature, using the closed head, might carry the reaction to completion more rapidly than heating at 204°F. as in normal Vacreator treatment, and so make possible direct removal of cress taint from bulk cream without the necessity for segregation.

Experimental.

Cream contaminated with latent cress taint was pasteurized in a Vacreator at a temperature of 222°F. and at maximum intensity of steam distillation. Churnings of butter were made from creams from the same bulk supply passed once, twice and three times through the Vacreator under these conditions. There was no evidence that the repeated treatment of the cream was effective in reducing the intensity of cress taint in the butter.

DISCUSSION

The results detailed above indicate some practical measures which may be adopted for the handling of cress-contaminated cream in the commercial factory. Use of low pasteurization temperatures eliminates the necessity for segregating the cress cream, but it introduces a danger to keeping quality of the butter. For butter which has to withstand the storage conditions applied in the New Zealand export trade, presence of cress taint is preferable to poor keeping quality. This method should not be used for poor quality cream. Segregation of the cress-contaminated cream, and boiling up with steam for 30 min. prior to Vacreator treatment, is more troublesome but is fraught with less danger to the butter quality.

The results cited do not throw much light on the nature of the reaction occurring in the development of cress taint. It is suggested, as a working hypothesis, that a mother substance passes into the milk of cows consuming land cress, and that the substance is gradually destroyed by heat to form the true land cress taint. The critical temperature for development of true land cress taint from latent cress taint is in the region where the formation of sulphide compounds from the milk proteins takes place. The work described in the present paper does not provide evidence to indicate whether development of cress taint in the cream and the formation of sulphides are interconnected, or whether they are merely coincidental.

ACKNOWLEDGMENTS

The authors desire to acknowledge their indebtedness to Messrs. Murray Deodorizers Ltd., and especially to Mr. H. Lamont Murray, for extensive assistance in the development and trials of the various modifications of the Vacreator, and for helpful advice throughout the investigation. Warm thanks are due to the Directors of the Tauranga Co-op. Dairy Co., for facilities provided in their factory for much of the experimental work, and to their (then) Managers, (the late) Mr. E. Gilbert and Mr. R. A. Harvey, for much assistance received.

Acknowledgments are due also to Professor Riddet for much helpful advice, to Dr. R. M. Dolby for assistance in the arrangement of the experimental work, to Dr. H. R. Whitehead for the bacteriological analyses, and especially to the Department of Agriculture Dairy Produce Graders at Wellington and Auckland for their regular examinations of the experimental butters.

REFERENCES

- 1 McDOWALL, F. H., MORTON, I. D. and McDOWELL, A. K. R (1947): *N. Z. J. Sci. Tech. A*, 28, 305-15 (Dairy Res. Inst. (N.Z.) Publ. 194).
- 2 McDOWALL, F. H., MORTON, I. D. AND O'DEA, J. J. (1947): *Ibid*, A, 28, 370-84 (*Ibid*, 199).

LAND-CRESS TAINT IN CREAM AND BUTTER

VI. FURTHER EXPERIMENTS ON THE CONTROL GRAZING OF LAND-CRESS INFESTED PASTURES.

By F. H. McDOWALL, J. A. SINGLETON, and J. J. O'DEA, The Dairy
Research Institute (N.Z.), Palmerston North

Summary

Cress-taint was found to be frequently present in the morning's milk and cream from cows milked at 5.30 a.m. after grazing overnight on a cress-infested pasture. This would indicate that the extent of the control grazing self-imposed by the cows, as a result of their habit of grazing mainly during the early part of the night period, is not sufficient to ensure absence of cress taint in the cream and butter from the morning's milk.

INTRODUCTION

CONSUMPTION of land-cress plant material by milking cows usually leads to the appearance of land-cress taint in the milk or cream. If the period intervening between time of consumption of the cress and time of milking is several hours, the tainting substances may be eliminated from the cow's system before the milk is drawn. Control grazing, i.e. removal of the herd from the cress-infested area several hours before milking-time, has been recommended as a means of preventing, or at any rate of reducing, the intensity of cress taint¹. Levy² has reported that at night cows graze mainly during the period between evening milking-time and about 12 p.m., and that thereafter until morning-milking they are resting. Control grazing over the night period is scarcely practicable, since it would require the attendance of a member of the farm staff at the grazing area at midnight; and there would be difficulty in transferring the herd during darkness. From the above-mentioned findings of Levy, however, it seemed possible that a cress-infested paddock might safely be grazed during the night, giving a control grazing self-imposed by the cows.

EXPERIMENTAL

A farm with a heavily-infested cress area, and with a number of cress-free paddocks, was available. At the beginning of the experiment, the herd of 17 cows was grazed on the cress-infested area during the day. The milk, cream and butter showed strong cress taint. Thereafter the cows were turned on to a clean area during the day, and on to the cress-infested area after the evening milking at 6 p.m. The cows were milked the following morning at 5.30 a.m. The evening's and morning's creams were collected separately, and were flash-pasteurized and churned. The butters were graded at the Dairy Research Institute, and by Department of Agriculture Graders at Wellington and Auckland. In the butter made from evening creams no cress-taint was detected by any of the graders. In Table I below are set out some typical results from a series of 30-day trials on the grading of butters from morning creams. It is apparent that as a means of preventing the incidence of cress taint in cream and butter the grazing of cows on a cress-infested area at night is not so effective as controlled grazing during the day.

TABLE I. GRADING RESULTS OF BUTTERS FROM MORNING CREAMS FROM COWS GRAZED ON A CRESS-INFESTED AREA DURING THE NIGHT

<i>Dairy Research Institute.</i>	<i>Wellington.</i>	<i>Auckland.</i>
Strong Cress	—	Strong Cress
Cress	—	Cress
Slight Cress	Trace Cress	Feedy
Cress	Intense Cress	Cress
Cress	Intense Cress	Cress
Cress	Intense Cress	Cress
Cress	Strong Cress	Strong Cress

As stated in a previous paper, cress-infested pastures should be grazed with dry stock; but where the infestation is so widespread that grazing of the cows on the infested area cannot be avoided, the only safe method is to apply a system of controlled grazing during the day, with removal of the cows from the infested area not later than four hours before milking-time. In some instances it may be found necessary to increase the period allowed for elimination of the cress taint from the cow's system to five or six hours. The actual length of the period required varies with the proportion of cress present in the pasture, and, apparently, with the general condition of the cows at time of consuming the cress.

ACKNOWLEDGMENT

The authors' thanks are due to Mr. C. E. Perry for assistance in the controlling of the time of grazing of the cows on the cress-infested area, and in supplying the morning and evening creams separately as required.

REFERENCES

- (1) McDOWALL, F. H., MORTON, I. D., O'DEA, J. J., and ALLO, A. V. (1947): *N.Z. J. Sci. Tech.*, A, 28, 370-84. (Dairy Research Institute (N.Z.) Pub. 199.)
- (2) LEVY, E. B. (1935): *N.Z. J. Agr.* 50, 135-47.

PASTEURIZATION OF CREAM AT HIGH TEMPERATURES IN THE VACREATOR VACUUM-PASTEURIZER IN RELATION TO THE QUALITY OF BUTTER

By F. H. McDOWALL, J. A. SINGLETON and J. J. O'DEA, The Dairy
Research Institute (N.Z.), Palmerston North

(Received for publication, 23 August, 1950)

Summary

Pasteurization of cream at 220°F. and at 212°F. in a Vacreator vacuum-pasteurizer fitted with a closed head gave consistently a slight improvement in the grade of the fresh butter, as compared with pasteurization at 202°F. This advantage was maintained in butters from both good and poor quality creams over 4 months' storage at 14°F.; and it was maintained over 8 months' storage in butters from good quality cream but not in butters from poor quality cream. The differences were not due to a lowering of the bacteria count by high temperature pasteurization, but appear to have been caused by the effect of the high temperature of heating on the flavour characteristics of the cream, giving a more "nutty" flavour to the butter.

INTRODUCTION

THE maximum temperature of pasteurization of cream in a Vacreator vacuum-pasteurizer fitted with the standard float-type feeder tank is 206-208°F. Attempts to raise the cream temperature above 208°F. usually result in blow-back of steam past the float-tank valve. The float-type feeder-tank has recently been replaced, in many New Zealand factory installations, by a closed head. The cream is pumped direct into the pasteurizer section through the inlet pipe in the closed head. The steam pressure in this section can then be raised above atmospheric pressure, making possible the pasteurization of cream at temperatures above the boiling point of water. The maximum pressure (and therefore the maximum temperature) obtainable, is limited by structural considerations. Raising of the pressure in the pasteurizing section also imposes one or other of two readjustments in the system of operation of the Vacreator: (a) if it is desired to maintain the degree of partial vacuum in the first separating-chamber at the same value as previously applied in the treatment of cream using the float-tank feeder assembly, a stronger tension is required on the Bowden wire controlling the equilibrium-valve lever, in order to maintain the larger temperature differential and, therefore, a larger pressure differential, across this valve; or (b) the degree of partial vacuum applied to the cream in the first separating-chamber must be reduced, thus giving higher distillation temperatures to this section. For the treatment of "feedy" or other weed-tainted cream requiring extensive deodorization, the higher temperature of steam distillation can be expected to result in more efficient removal of off-flavours, since the vapour pressure of the off-flavouring substances is likely to rise more rapidly with rise in temperature than the vapour pressure of water.

Because of the possible effect of the higher temperatures in causing formation of a brown casein film on the inside surface of the pasteurizer section, it is essential that all superheat be removed from the steam by injection of a small stream of water through the humidifier valve.

The effect of high-temperature pasteurization of cream on the properties and keeping quality of butter has not been extensively studied.

Roberts, Coulter and Combs¹, comparing flash-pasteurization of cream at 260°F. in a laboratory model of the Rogers high temperature cream-pasteurizer with vat pasteurization of similar cream at 160°F., reached the following conclusions :

"(1) Cream which was essentially sterile as determined by the standard plate count was obtained from either sweet or neutralized sour cream by pasteurization at 260°F., using a laboratory model high-temperature steam-injection pasteurizer.

(2) Salted and unsalted butter churned from such cream, although having a slight cooked flavour while fresh, received the same flavour score as butter churned from different lots of the same cream vat-pasteurized at 160°F.

(3) Despite lower initial bacterial counts neither salted nor unsalted butter churned from cream pasteurized at 260°F. in the high-temperature steam-injection pasteurizer kept better in storage at 40°F. than butter from different lots of the same cream vat-pasteurized at 160°F.

(4) The fat loss in the buttermilk was much greater in the churning of cream flash-pasteurized at 260°F. than in the churning of cream vat-pasteurized at 160°F."

There are, at time of writing (Jan. 1949), no publications describing the effect of high temperature pasteurization of cream, with use of the pressure head on the Vacreator vacuum-pasteurizer, on the quality of the resultant butter.

EXPERIMENTAL PROCEDURE

The creams were pasteurized and churned in the experimental factory at the Dairy Research Institute (N.Z.). Farm-separated cream, of varied character for the different series of trials, was obtained from a neighbouring factory. It was bulked in one vat at the Institute and was divided into two or three equal portions. The creams were treated in a "Baby" Vacreator vacuum-pasteurizer provided with closed-head attachment. The temperatures of pasteurization were varied as set out in the Tables given below. The pressure in the first separating-chamber was maintained at 12 in., and the degree of steam distillation applied, i.e., the temperature rise in the condenser water, was kept constant for all batches of cream on any one day. The creams (about 400 lb. in each churning) were churned, and the butters were salted and worked, in an internal-worker churn. The salt and moisture contents were kept uniform for the butters from all churnings on any one day. The only difference between the treatment of the creams from the separate churnings each day was, therefore, the difference in pasteurizing temperature.

The butters were examined :

- (a) In the fresh state by three groups of experienced Graders—Panels A, B and C ;
- (b) after 4 months' storage at 14°F. by Panels A and B ;
- (c) after 8 months' storage at 14°F. by Panels A and B.

RESULTS

Five series of comparisons were made over the period 1944-1948. Series I, II, III and IV trials were made with good quality farm-separated cream, and Series V trials with poor quality farm-separated cream.

*Grade Scores of Butters**Series I Trials.*

Direct comparison was made of pasteurization at 212°F. and at 200°F. The results are given in Table I.

TABLE I. AVERAGE GRADE SCORES OF BUTTERS FROM CREAMS PASTEURIZED AT 212°F. AND AT 202°F. (5 COMPARISONS, NOVEMBER, 1944-FEBRUARY, 1945)*

Age of Butter at Time of Grading.	Panel by which graded.	Average Grade Score of Butters from Cream Pasteurized at		Difference in Grade Score in Favour of Pasteurization at 212°F.
		212°F.	202°F.	
Fresh	A	93.60	93.10	+0.50
	B	93.20	92.65	+0.55
	C	93.50	92.62	+0.88
	Average	93.43	92.78	+0.65
4 Months	A and B	92.56	92.00	+0.56
8 Months	A and B	91.85	91.75	+0.10

* Since the results were for the most part uniform, showing differences of approximately the same magnitude and consistently in the same direction, it has not been thought necessary to treat them statistically.

Series II Trials.

Direct comparison was made between pasteurization at 220°F. and at 212°F. and pasteurization at 202°F. The results are given in Table II.

TABLE II. GRADE SCORES OF BUTTERS FROM CREAMS PASTEURIZED AT 220°F., 212°F. AND 202°F. (9 COMPARISONS, MARCH-APRIL, 1945)

Age of Butter at Time of Grading.	Panel by which Graded.	Average Grade Scores of Butters from Creams Pasteurized at			Differences in Grade Score in Favour of Pasteurization at.	
		220°F.	212°F.	202°F.	220°F.	212°F.
Fresh	A	93.82	93.79	93.65	+0.17	+0.14
	B	93.17	93.53	93.06	+0.11	+0.47
	C	93.48	93.58	93.35	+0.13	+0.23
	Average	93.49	93.63	93.35	+0.14	+0.28
4 Months	A and B	92.32	92.50	92.14	+0.18	+0.36
8 Months	A and B	91.67	91.84	91.39	+0.28	+0.45

Series III Trials.

Direct comparison was made between pasteurization at 212°F. and pasteurization at 202°F. Results are given in Table III.

TABLE III. AVERAGE GRADE SCORES OF BUTTERS FROM CREAMS PASTEURIZED AT 212°F. AND 202°F. (10 COMPARISONS, 6/9/46-24/1/47)

Age of Butter at Time of Grading.	Panel by which Graded.	Average Grade Score of Butters from Cream Pasteurized at		Difference in Grade in Favour of High Temperature Pasteurization.
		212°F.	202°F.	
Fresh	A	93.1	93.1	±0
	B	93.35	93.05	+0.30
	C	92.55	92.62	-0.07
	Average	93.00	92.92	+0.08
4 Months	A and B	92.88	92.78	+0.10
8 Months	A and B	92.68	92.28	+0.40

Series IV Trials.

Direct comparison was made between vacreator vacuum-pasteurization at 220°F. and 212°F. and similar pasteurization at 202°F. Results are given in Table IV.

TABLE IV. AVERAGE GRADE SCORES OF BUTTERS FROM CREAMS PASTEURIZED AT 220°F., 212°F. AND 202°F. (4 COMPARISONS, GOOD QUALITY FARM-SEPARATED CREAM, 25.3.47-3.4.47)

Age of Butter at Time of Grading.	Panel by which Graded.	Average Grade Score of Butter from Cream Pasteurized at			Difference in Grade in Favour of Pasteurization at	
		220°F.	212°F.	202°F.	220°F.	212°F.
Fresh	A	93.69	94.00	93.75	-0.06	+0.25
	B	93.25	93.25	92.94	+0.31	+0.31
	C	93.22	93.75	93.62	-0.40	+0.13
	Average	93.39	93.67	93.44	-0.05	+0.23
4 Months	A and B	92.94	93.06	92.50	+0.44	+0.56
8 Months	A and B	92.31	92.75	91.88	+0.43	+0.87

Series V Trials.

Direct comparison was made between vacreator vacuum-pasteurization at 220°F. and 212°F. with similar pasteurization at 202°F. using poor quality cream.* Results are given in Table V.

TABLE V. AVERAGE GRADE SCORES OF BUTTERS FROM CREAMS PASTEURIZED AT 220°F., 212°F. AND 202°F. (14 COMPARISONS—POOR QUALITY CREAM, 29/10/47-8/4/48)

Age of Butter at Time of Grading.	Panel by which Graded.	Average Grade Score of Butter from Cream Pasteurized at			Difference in Grade in Favour of Pasteurization at	
		220°F.	212°F.	202°F.	220°F.	212°F.
Fresh	A	92.29	91.98	91.43	+0.86	+0.55
	B	91.63	91.46	91.30	+0.33	+0.16
	C	91.73	91.78	91.78	-0.05	±0
	Average	91.82	91.74	91.50	+0.41	+0.24
4 Months	A and B	90.32	89.91	89.66	+0.66	+0.25
8 Months	A and B	89.29	88.82	88.82	+0.47	±0

Bacteriological Examination of Creams and Butters

Bacteriological counts on the creams after pasteurization and on the butters in Series IV and in Series V trials were made by the plate method, using whey-agar medium; *B. coli* was estimated by the McConkey-tube method. The plate counts on the creams in the holding-vats were of the order of 1,000 to 30,000, and there was no significantly consistent difference in the counts for the creams pasteurized at the different temperatures. While every care was taken as far as possible to sterilize all equipment before use, there was a general tendency for the first run of cream each day to be slightly higher in count than the later cream. It was evident that the effect on the bacterial population of contamination of the cream from coolers, pumps and churns, was greater than any difference in efficiency of pasteurization caused by the differences in temperature of pasteurization. The average results for the plate counts on the butters are given in Table VI.

* The cream was of poor quality due to bacterial action and not to the presence of "feedy" or other similar off-flavours.

TABLE VI. BACTERIOLOGICAL EXAMINATION OF BUTTERS FROM SERIES IV AND SERIES V TRIALS

Series No.	Age of Butter.	Average Number of Bacteria per Gram as Estimated by Plate Counts on Butters from Creams Pasteurized at		
		220°F.	212°F.	202°F.
IV	Fresh	18,000	19,000	25,000
V	Fresh	19,000	12,000	3,000
	4 Months	107,000	44,000	111,000
	8 Months	12,000	10,000	8,000

Chemical Examination of Butters after Storage.

Butterfats were isolated, by melting and filtering, from samples of the butters in Series V trials after 8 months' storage. Estimations of Lea peroxide values, of Schibsted fat-aldehyde values and of fat acidities were made on each butterfat (see Table VII).

TABLE VII. CHEMICAL EXAMINATION OF BUTTERFATS FROM BUTTERS IN SERIES V TRIALS, AFTER 8 MONTHS' STORAGE AT 14°F.

Chemical Estimation.	Average Value for Butters from Creams Pasteurized at		
	220°F.	212°F.	202°F.
Lea Peroxide Value	0.45	0.33	0.30
Schibsted Fat			
Aldehyde Value	1.11	0.72	0.74
Fat Acidity Value	0.21	0.22	0.23

DISCUSSION

The average grading results for the butters in Series I-V are given in Table VIII. The grading results for the daily comparisons in any one series varied to some extent, as could be expected in view of the possible variations in contamination during manufacture, slight unavoidable variations in conditions of manufacture and in salt content of the butter for any one day, and the possible errors inherent in any subjective grading test. The trials extended over a long period during the season, and it is conceivable that the effect of high temperature pasteurization on cream and butter quality may vary with the type of cream being handled. The effects of high temperature pasteurization, as indicated by the average grading results for the separate series, also show some variations.

Grading of Fresh Butters.

Pasteurization at 220°F. had only a slight influence on the grading of the butter from good quality cream immediately after manufacture, but did give a distinct improvement in the fresh butter from poor quality cream, as compared with pasteurization at 202°F. Pasteurization at 212°F. gave a slight but consistently evident improvement in the grade of the fresh butter (average about 0.3 grade points) as compared with pasteurization at 202°F., for butters both from good quality and from poor quality creams. The results for bacteriological examination of the creams and fresh butters show that any difference in flavour of high temperature pasteurization could not be attributed to greater efficiency

in pasteurization, since the efficiency of pasteurization was satisfactory for all these creams, being independent of pasteurization temperature. The higher temperature of pasteurization gave the cream and fresh butter a somewhat more distinct "nutty" flavour, which appears to be the cause of the slight preference for these butters.

TABLE VIII. SUMMARY OF GRADING RESULTS, SERIES I-V

Series No.	Type of Cream used.	Number of Comparisons.	Age of Butter when Graded.	Difference in Average Grade Score in Favour of Pasteurization at			
				220°F.	Average Difference.	212°F.	Average Difference.
I	Good Quality	5	Fresh	—		+0.65	
II	"	9	"	+0.14		+0.28	
III	"	10	"	—		+0.08	
IV	"	4	"	-0.05	+0.08	+0.23	+0.27
V	Poor Quality	14	"	+0.41	+0.41	+0.24	+0.24
I	Good Quality	5	4 Months	—		+0.56	
II	"	9	"	+0.18		+0.36	
III	"	10	"	—		+0.10	
IV	"	4	"	+0.44	+0.26	+0.56	+0.33
V	Poor Quality	14	"	+0.66	+0.66	+0.25	+0.25
I	Good Quality	5	8 Months	—		+0.10	
II	"	9	"	+0.28		+0.45	
III	"	10	"	—		+0.40	
IV	"	4	"	+0.43	+0.33	+0.87	+0.43
V	Poor Quality	14	"	+0.47	+0.47	±0	±0

Grading of Butters at 4 Months.

When the butters were examined at 4 months there was a consistent preference for those from the cream pasteurized at the higher temperatures independent of the type of cream used. With good quality cream, pasteurization at 212°F. gave slightly better results than pasteurization at 220°F., but with poor quality cream pasteurization at 220°F. gave butters with the highest grading at 4 months. The remarks of the graders on the qualities of the butters do not indicate any consistent cause for the higher grade of the butters from creams pasteurized at high temperatures other than that there was slightly less storage flavour in these butters.

Grading of Butters at 8 Months.

The beneficial effect of high temperature pasteurization was maintained in the butters from good quality cream pasteurized at both 220°F. and 212°F. after 8 months' storage, but it was not maintained in the butters from poor quality creams pasteurized at 212°F. Where the beneficial effect of high temperature pasteurization was evident, it could be attributed to a slight reduction in the intensity of storage flavour.

Relation of Results for Bacterial Counts (Table VI) and for Chemical Examinations of Butters after Storage to Gradings of Butters.

The results in Table VI show that there was no appreciable difference in the bacteriological condition of the butters from the creams pasteurized at the three different temperatures, and the results for Lea

peroxide value and Schibsted fat-aldehyde value (Table VII) show that the advantage in grade score gained by the butters from creams pasteurized at 220°F. could not be attributed to the effect of the more intense heat treatment on the degree of oxidation of the butterfats in the butters.

The results for fat acidities in the butterfats from the butters (Table VII) show that the advantage of high temperature pasteurization was not due to more thorough destruction of lipase enzymes by this more intense heat treatment.

Rate of Percentage Butterfat Loss.

The rate of percentage of butterfat loss from creams pasteurized and churned under the small-scale experimental conditions at the Dairy Research Institute are higher than obtain in commercial practice². The average values for Series III-V trials given in Table IX, should therefore not be taken as indicative of the magnitude of the losses to be expected under large-scale conditions of buttermaking. The results, however, have a comparative value, and show that high temperature pasteurization, under the conditions specified above, caused a slight increase in rate of butterfat loss in the buttermilk.

TABLE IX. PERCENTAGE RATES OF BUTTERFAT LOSS IN CHURNING, AS CALCULATED BY McDOWALL'S MODIFICATION OF THE BIRD AND DERBY FORMULA

Trial Series.	Percentage Rate of Butterfat Loss from the Churning of Cream Pasteurized at		
	220°F.	212°F.	202°F.
III	2.24	2.24	1.84
IV	2.16	2.27	2.13
V	2.08	1.89	1.54
Average	2.16	2.13	1.83

ACKNOWLEDGMENTS

The authors desire to express their thanks to Mr. W. R. Mummery of this Institute for assistance with the analytical work, and to the Department of Agriculture Dairy Produce Graders at Wellington and Auckland for assistance in the examination of the butters.

REFERENCES

- 1 ROBERTS, W. M., COULTER, S. T. and COMBS, W. B. (1940): *J. Dairy Sci.*, 23, 315.
- 2 McDOWALL, F. H. (1938): *N.Z. J. Sci. Tech.*, 19, 682-90 (*Dairy Research Institute (N.Z.) Pubn. No. 110*).

SPRAY TREATMENTS WITH DDT FOR CONTROL OF CODLING MOTH (*Cydia pomonella* L.) IN APPLE ORCHARDS

By G. G. TAYLOR, Plant Diseases Division, Department of Scientific
and Industrial Research, Auckland

(Received for publication, 6 December, 1950)

Summary

Field experiments on apples of the Sturmer variety in Hawkes Bay and Auckland showed that DDT, 2 oz. *p,p'* isomer to 100 gal. water applied at normal intervals throughout the season, gave control of codling moth comparable with that given by lead arsenate at 2 lb. to 100 gal. Much improved control was secured with DDT, 4 oz. *p,p'* isomer to 100 gal. whilst higher dosages appeared to be unnecessary for practical purposes. It was shown that DDT sprays applied from January onwards were more important in codling moth control than applications made earlier in the season.

Where DDT was applied throughout the season red-mite populations sometimes became heavy due to eradication of predacious insects. It was shown that by using lead arsenate, 2 lb. to 100 gal. water up to mid-December and then introducing DDT, 4 oz. *p,p'* isomer to 100 gal., for later sprays, adequate control of codling moth was secured with minimum harm to beneficial predators.

INTRODUCTION

In a previous paper (Taylor, 1951), it was shown that under conditions of efficient spray application, the standard treatment of lead arsenate 1½-2 lb. to 100 gal. water applied from complete petal-fall at intervals of 14-18 days up to 21 days before harvest gave satisfactory control of codling moth. In commercial orchards, however, where methods of application often fail to give maximum coverage, the overwintering populations of larvae are high, and trees become re-infested each year with consequent losses not only from grub-infested fruit, but by degrading of apples damaged by "stings". It has also been shown (Taylor, 1951) that damage to fruit and foliage by lead arsenate is an objection to its use on some varieties.

With the introduction of DDT, the problem has been radically changed. The greater efficacy of DDT has made control of codling moth possible under conditions of spraying which would be inadequate with lead arsenate. At the same time its lower phytocidal action provides a means of avoiding tree injury associated with the use of lead arsenate.

Several practical difficulties have arisen where DDT is used in place of lead arsenate. DDT does not kill red mites on apple trees, but does kill predacious insects which normally hold mites in check. Consequently trees may become infested with abnormally large populations of mites early in the season following the use of DDT. A limitation is placed on the use of DDT at the blossom period because of its toxicity to bees. It has been shown, however, that once flowering is completed, bees do not suffer injury even though hives are located close to sprayed trees.* DDT does not control woolly aphis but is known to reduce populations of the parasite *Aphelinus mali* Hald., thereby upsetting the biological balance in favour of the pest.

* Information supplied by W. Cottier, Senior Entomologist, Plant Diseases Division, Department of Scientific and Industrial Research, from unpublished experiments.

Thus, in determining the role of DDT in codling moth control it is important to know the minimum dosages and optimum periods of the year at which it can be used most successfully to give commercial control. Data relating to these two aspects of the problem are given in the present paper.

EXPERIMENTAL METHODS

All treatments were applied to orchard trees by conventional spraying methods using twin nozzles on a 6-ft rod, operating at a nozzle pressure of 350 lb. per square inch, and delivering approximately 3.5 gal. per minute. The Sturmer variety was used in all but one trial as it is highly susceptible to attack by codling moth. Trees were selected for spraying in orchards where the incidence of codling moth was known to be high. Two or more trees were included in each plot. Treatments were randomized within blocks and each block was replicated at least four times.

A wettable DDT powder was used in which 95 per cent. of particles passed a 300-mesh British standard sieve. In the text and tables, all dosages are given in terms of *p,p'* isomer of DDT. The acid lead arsenate employed was a wettable powder in which 90 per cent. of particles were less than 10μ in diameter and water soluble arsenic was less than 0.2 per cent. as arsenic pentoxide. All treatments were used in combination with colloidal sulphur paste (40 per cent. sulphur) 2 lb. to 100 gal., with the addition of 3 lb. hydrated lime to 100 gal. where lead arsenate was used. Where check trees were used these received fungicides at normal intervals but no insecticides.

Records were taken from windfalls and from the harvested crop and are shown as percentages of apples damaged by larvae established in the fruit, i.e., "internal grub", and as percentages of apples showing superficial damage caused by attempted entry of larvae, i.e., "stings". Results have been analysed statistically, either directly on percentages or, where differences between treatments varied widely, on their equivalent angles. Differences in red mite populations were recorded by observation only. In none of the trials here reported was woolly aphis attack severe and consequently no critical comparisons between populations on different treatments could be made.

RESULTS

Dosage Rates of DDT compared with Lead Arsenate.

Auckland 1945/46 season: Results given in Table I show that at a dosage rate of 1 oz. DDT to 100 gal., control comparable to that from a standard lead arsenate treatment was secured. At 4 oz. DDT to 100 gal. damage from internal codling grub was significantly reduced.

TABLE I. DOSAGE RATES OF DDT COMPARED WITH LEAD ARSENATE (LA) FOR CONTROL OF CODLING MOTH ON STURMER APPLES. AUCKLAND, 1945/46 SEASON

*Quantity insecticide per 100 gal.	Percentage fruits damaged by	
	Stings.	Internal grub.
1. LA $1\frac{1}{2}$ lb.	11.1	7.9
2. DDT 1 oz.	9.2	7.1
3. DDT 4 oz.	5.7	2.0
4. DDT 16 oz.	2.7	0.3
Diff. for significance at 5%	3.8	3.0

* Applied 6 and 20 Nov., 5 and 19 Dec., 23 Jan., 13 Feb. and 8 Mar.

Infestation by red mite was more severe on DDT than on lead arsenate treatments.

Hawkes Bay 1946/47 season: In Table II are given results of a trial similar to that described above. At 2 oz. to 100 gal., DDT gave control comparable with a standard lead arsenate treatment. At 4 oz. DDT to 100 gal., a significant reduction was secured in percentage fruit damaged by codling stings.

Increased populations of red mite occurred where DDT was used, the increase being most apparent at the higher dosage rates.

TABLE II. DOSAGE RATES OF DDT COMPARED WITH LEAD ARSENATE FOR CONTROL OF CODLING MOTH ON STURMER APPLES. HAWKES BAY, 1946/47 SEASON

*Quantity insecticide per 100 gal.		Percentage fruits damaged by	
		Stings.	Internal grub.
1.	LA 2 lb.	19.9	1.0
2.	DDT 1 oz.	25.2	2.2
3.	DDT 2 oz.	21.2	1.3
4.	DDT 4 oz.	8.9	0.2
5.	DDT 8 oz.	4.6	0.2
Diff. for significance at 5%		7.2	1.3

* Nine sprays applied commencing 2 Nov. and finishing 18 Mar.

Critical Period for DDT Applications.

Hawkes Bay 1947/48 season: In Table III results are reported from an experiment in which treatments with DDT were commenced at successively later dates in the growing season. Results show that with delay in the commencement date of spraying codling moth injury increased. However, it was not until the first application was delayed until 2 January, in Treatment 3, that significant increase in damage occurred. Where the commencement of spraying was further delayed until 25 January, the extent of codling moth damage showed a considerable increase.

TABLE III. CRITICAL PERIOD FOR COMMENCEMENT OF DDT SPRAYS AGAINST CODLING MOTH ON STURMER APPLES. HAWKES BAY, 1947/48 SEASON

Quantity insecticide per 100 gal. (oz.)	*Commencing date of applications.	Percentage fruits damaged by		Equivalent angles for internal grub.
		Stings.	Internal grub.	
1. 8	12 Nov.	6.8	0.6	3.9
2. "	12 Dec.	10.0	2.9	9.3
3. "	2 Jan.	19.5	8.9	17.3
4. "	25 Jan.	16.7	25.8	30.1
5. "	16 Feb.	20.1	33.5	34.9
6. Check	No insecticide	19.3	48.8	43.2
Diff. for significance at 5%		5.6	—	6.6

* Spraying dates for the whole season were 12 Nov., 12 Dec., 2 and 25 Jan., 16 Feb. and 16 Mar.

In this trial, spray treatments to control red mite were applied at petal-fall and consequently the effects of DDT sprays on the density of red-mite populations could not be assessed.

Hawkes Bay 1947/48 season : Results given in Table IV are from an experiment similar to that described above. They show that delay in the commencement date of spraying until 23 December caused a small but significant increase in percentage fruit damaged by internal grub. Where spray treatments were commenced on 13 January significant increases occurred in percentage fruits damaged by stings and by codling grub as compared with the complete programme of DDT sprays in Treatment 1.

TABLE IV. CRITICAL PERIOD FOR COMMENCEMENT OF DDT SPRAYS AGAINST CODLING MOTH ON STURMER APPLES. HAWKES BAY, 1947/48 SEASON

Quantity insecticide per 100 gal.	*Commencing date of application.	Percentage fruits damaged by Stings.	Internal grub.
1. DDT 8 oz.	3 Nov.	3.0	0.3
2. " "	19 Nov.	4.9	0.3
3. " "	8 Dec.	4.6	2.2
4. " "	23 Dec.	5.1	2.9
5. " "	13 Jan.	9.5	9.9
6. LA 2 lb.	3 Nov.	6.1	2.3
Diff. for significance at 5%		5.2	2.4

* Spraying dates for whole season were 3 and 19 Nov., 18 and 23 Dec., 13 Jan., 2 and 24 Feb. and 19 Mar.

Red mite developed on all treatments but was most severe where applications of DDT were commenced at petal-fall.

Auckland 1947/48 season : Results given in Table V are from a trial similar to those described above. Delay in application dates of DDT had much the same effect as occurred in the Hawkes Bay experiments. Thus, it was not until the first application was delayed until 7 January that a significant increase in codling moth injury developed.

Infestation by red mite in this trial was slight, and no differences between treatments were apparent.

TABLE V. CRITICAL PERIOD FOR COMMENCEMENT OF DDT SPRAYS AGAINST CODLING MOTH ON GRANNY SMITH APPLES. AUCKLAND, 1947/48 SEASON

Quantity insecticide per 100 gal.	*Commencing date of application.	Percentage fruits damaged by Stings.	Internal grub.
1. DDT 8 oz.	18 Nov.	2.6	1.6
2. " "	17 Dec.	2.6	2.3
3. " "	7 Jan.	4.2	7.7
4. Check	No insecticide	6.7	47.3
Diff. for significance at 5%		2.5	2.7

* Application dates for the whole season were 18 Nov., 17 Dec., 7 and 28 Jan., 18 Feb. and 11 Mar. Percentage infections from check plots were not included in the analysis of variance.

Substitution of DDT for Lead Arsenate at Different Periods.

Hawkes Bay 1947/48 season : Treatments and results set out in Table VI show that by using lead arsenate alone in the early summer and substituting DDT, 4 oz. to 100 gal., from January onwards significant improvement in control of internal grub was attained, as compared with the use of lead arsenate alone throughout the season. The former treatment gave results comparable with those from the use of DDT at 8 oz. to 100 gal.

TABLE VI. DDT AND LEAD ARSENATE IN THE SAME PROGRAMME COMPARED WITH DDT AND LEAD ARSENATE ALONE FOR CONTROL OF CODLING MOTH ON STURMER APPLES. HAWKES BAY, 1947/48 SEASON

Quantity insecticide per 100 gal.	Dates of applications.	Percentage fruits damaged by Stings.	Internal grub.
1. LA 2 lb.	31 Oct. 17 Nov. 10 and 29 Dec. 20 Jan. 11 Feb. and 5 Mar.	5.6	3.4
2. LA 2 lb.	31 Oct. 17 Nov. 10 and 29 Dec.	6.3	1.0
DDT 4 oz.	20 Jan. 11 Feb. 5 Mar.		
3. DDT 8 oz.	31 Oct.	5.1	0.7
LA 2 lb.	17 Nov. 10 and 29 Dec.		
DDT 4 oz.	20 Jan. 11 Feb. 5 Mar.		
4. DDT 8 oz.	As for Treatment 1 above	4.8	0.5
Diff. for significance at 5%		2.5	1.6

Red mite infestation developed earlier in the season and was more extensive in the complete DDT spray programme of Treatment 4 than in any other treatment.

TABLE VII. DDT AND LEAD ARSENATE IN THE SAME SPRAY PROGRAMME COMPARED WITH DDT AND LEAD ARSENATE ALONE FOR CONTROL OF CODLING MOTH ON STURMER APPLES. HAWKES BAY, 1948/49 SEASON

Quantity insecticide per 100 gal.	Dates of applications.	Percentage fruits damaged by Stings.	Internal grub.
1. LA 1½ lb.	29 Oct. 13 and 27 Nov. 22 Dec. 8 and 28 Jan. 17 Feb. and 9 Mar.	13.3	2.3
2. DDT 8 oz.	As in Treatment 1	2.5	0
3. LA 1½ lb.	29 Oct.		
DDT 4 oz. + LA 1½ lb.	As in Treatment 1 above from 13 Nov.	2.9	0.2
4. DDT 8 oz. LA 1½ lb.	29 Oct. and 8 Jan. Remaining dates as in Treatment 1 above	9.3	1.2
Diff. for significance at 5%		2.0	1.3

Red mite infestation was slight in the early summer. During January an application of summer oil was made to control this pest before any differences between treatments could be observed.

Hawkes Bay 1948/49 season: Results given in Table VII show that DDT, 8 oz. to 100 gal., introduced at petal-fall on 29 October, and again in early January (Treatment 4) gave a significant reduction in percentage fruits damaged by codling stings as compared with use of lead arsenate alone. This programme was, however, less effective than the treatment in which DDT, 8 oz. to 100 gal., was used throughout the season (Treatment 2) and where DDT, 4 oz. to 100 gal., was combined with lead arsenate from 13 November onwards (Treatment 3).

DISCUSSION

Results of the trials reported show that DDT, used alone or to replace lead arsenate at various periods during the spraying season, can be expected to show marked improvement in codling moth control as compared with lead arsenate treatments normally employed. It is evident that dosage rates and period of applying sprays are important factors determining performance. Because of the harmful effect of DDT on beneficial insects it is also important that minimum dosage should be employed together with the least number of applications consistent with adequate control of codling moth.

The evidence presented shows that DDT, 2 oz. to 100 gal., will give control comparable to that of lead arsenate at 2 lb. to 100 gal. when used at normal intervals throughout the season. At 4 oz. to 100 gal. control is much improved, whilst higher dosage rates appear to be unnecessary for practical purposes.

Results of experiments recorded in Tables III and V show that loss from codling moth becomes progressively greater as the season advances. Where sprays are omitted up to mid-December, a slight increase in codling moth damage occurs. Further delay up to early January results in a marked increase in loss, but the greatest codling moth injury occurs where the commencement of spraying is delayed beyond this period.

In relating these two general findings, viz. optimum dosage and period of maximum efficacy, to commercial practice it must be remembered that the trials here reported were carried out under conditions of high infestation. Because of reduced numbers of overwintering larvae following the use of DDT, it can be reasonably expected that results obtained in commercial practice will be superior, in the second and later seasons, to those presented here. Results given in Table VI show that efficient control of codling moth can be obtained by using lead arsenate up to the end of December and introducing DDT, 4 oz. to 100 gal., from January onwards. Compared with the use of DDT throughout the summer, control is equally good and the risk of severe red mite infestation much less. In commercial orchards similar programmes have proved efficient. Damage by codling moth has been reduced not only in the season of spraying, but as a result of reduced numbers of overwintering larvae, control in the following season has been simplified.

REFERENCES

- TAYLOR, G. G. (1951): Spray injury from use of lead arsenate on apple trees. *N.Z. J. Sci. Tech.*, Sec. A, 32(6), 39-48
- (1952): Spray treatment with lead arsenate for control of codling moth (*Cydia pomonella* L.) on apple trees. *N.Z. J. Sci. Tech.* A 33(6), (in the press.)

MINERAL AND NITROGEN STATUS OF DOUGHERTY APPLE LEAVES AND FRUIT UNDER DIFFERENT FERTILIZER TREATMENTS

By JOYCE WATSON, Cawthron Institute, Nelson

(Received for publication, 25 May 1950)

Summary

The effects of long continued fertilizer treatments on the growth of Dougherty apple trees and on their foliage and fruit characteristics, are described. Chemical analyses of leaf and fruit samples show increases of nitrogen with treatments containing nitrogenous fertilizers. The omission of potash is shown by a reduction of at least 50 per cent in the amounts found in the leaves. The omission of phosphate in the manurial treatment is not revealed very clearly by either leaf or fruit analyses but fruit analyses seem to correlate better in this respect than leaf analyses. Magnesia contents are decidedly lower where potassic fertilizers have been included in the manurial treatments. Leaf samples are better than fruit samples for showing deficiencies of potash, magnesia and nitrogen.

INTRODUCTION

Tests with different fertilizer treatments on a block of Dougherty apple trees at the Annesbrook Orchard of the Cawthron Institute have been maintained for over twenty years. A paper by Rigg and Chittenden¹ reported the effect of some of the treatments on tree growth and yield of fruit in the 1939 season. Since that paper was published further deterioration has taken place in trees which have not received fertilizer or which have received incomplete manurial treatments.

It was thought desirable to record the effect of the different treatments on the present appearance of the trees, the foliage and the fruit, and to correlate the effects of the different manurial treatments with the mineral and nitrogen status of the leaves and fruit collected from representative trees.

EXPERIMENTAL METHOD

Fertilizer Treatments

Trees were available with the following treatments:—(1) No fertilizer; (2) Potash and nitrogen only; (3) Phosphate and nitrogen only; (4) Phosphate and potash only; (5) Phosphate, potash and nitrogen.

For the past 20 years the annual fertilizer treatments have been as follows:—

Treatment (2) K + N

2 lb ground limestone, 1 lb muriate of potash, and
2 lb sulphate of ammonia per tree.

Treatment (3) P + N

2 lb ground limestone, 2 lb basic superphosphate, and
2 lb sulphate of ammonia per tree.

Treatment (4) P + K

2 lb basic superphosphate, and 1 lb muriate of potash per tree.

Treatment (5) Complete

2 lb ground limestone, 2 lb basic superphosphate,
1 lb muriate of potash, and 2 lb sulphate of ammonia per tree.

Ground limestone at the rate of 10 lb per tree was applied over all the plots every five years, the last application being made in 1946. A cover crop of blue lupins for green manure was grown in the autumn in

three out of four years during the period of the experiment. A dressing of ground dolomite at the rate of 6 lb per tree was applied to all the trees in the spring of 1944. In the 1947-48 season, owing to unfavourable growth conditions throughout the orchard, a dressing of 1 lb nitrate of soda was given in December 1947 to all trees included in the experiment.

RESULTS

Effect of Different Treatments on Growth, Foliage and Fruit Characteristics

Trees without fertilizer have been stationary in growth for some years. They frequently show marked "die-back" of the main branches. The leaves are rather small and of poor colour. Fruit likewise tends to be small but is of good colour.

Trees with "K + N" treatment show little new growth and some "die-back" of the branches occurs. The leaves are dark green in colour with a purple tinge and a red pigmentation of the leaf stalk. The fruit is of good size and colour.

Trees with "P + N" treatment show pronounced "die-back" of the main branches; the bark is frequently of a reddish colour. The leaves are small and light green in colour. Some browning of the edges of the leaves was visible in the 1948-49 season but there was in this season no pronounced blackening of the edges frequently described by other observers as typical of potash deficiency. The fruit is of small size and poor in colour.

Trees with "K + P" treatment show very little "die-back" but growth is very short or absent. The leaves turn yellow much earlier than is the case with complete fertilizer treatment. The fruit ripens early, is of fair size, and is highly coloured.

Trees with complete fertilizer treatment still make good growth; the leaves are bright green and of good size. The fruit tends to be later in ripening and lacks the high colour of fruit from trees which have received the "K + P" treatment. Trees with complete treatment are now outstanding both in growth and yield of fruit.

Mineral and Nitrogen Status of Leaf and Fruit Samples from the different Treatments

Samples of leaves and fruit were taken during the 1946-47, 1947-48, 1948-49 seasons from trees receiving the different fertilizer treatments. The leaves were taken from leader growth only. The fruit samples were divided into flesh and pips which were analysed separately. The results obtained are shown in Tables I, II and III.

DISCUSSION

Nitrogen

The analyses of the leaves show that the "K + N" treatment resulted in the highest nitrogen content while the "no fertilizer" and "P + K" treatments gave the lowest figures. The use of additional nitrogen (1 lb nitrate of soda) over all trees in the 1947-48 season increased the amount of nitrogen in the leaves from all treatments, but the leaves from the "no fertilizer" and "P + K" treatments showed the greatest relative increase in nitrogen.

TABLE I. MINERAL AND NITROGEN STATUS OF LEAF SAMPLES UNDER DIFFERENT FERTILIZER TREATMENTS (ALL RESULTS ON THE DRY MATTER BASIS).

Treatment	Date of Sampling	Total Ash	Insol. Ash	Sol. Ash	CaO	MgO	P ₂ O ₅	K ₂ O	N ₂
		(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
No Fertilizer	29/4/47 9/3/48	7.60	0.21	7.39	2.75 2.86	0.63 0.60	0.24 0.34	0.50 0.77	1.53 2.11
K + N	29/4/47 9/3/48 6/4/49	7.33	0.26	7.07	2.63 2.41 2.00	0.51 0.34 0.49	0.20 0.34 0.27	1.10 1.59 1.56	1.83 2.33 2.12
P + N	29/4/47 9/3/48 6/4/49	8.93 8.57	0.27 0.19	8.66 8.38	3.72 2.93 3.02	0.72 0.61 0.85	0.24 0.34 0.24	0.42 0.67 0.75	1.58 2.29 1.75
P + K	29/4/47 9/3/48 6/4/49	7.75 7.68	0.26 0.30	7.49 7.38	2.92 2.77 2.51	0.44 0.42 0.42	0.34 0.38 0.52	1.16 1.35 1.72	1.45 2.34 1.28
P + K + N	29/4/47 9/3/48 6/4/49	7.63 6.52	0.29 0.21	7.34 6.31	2.88 2.65 1.95	0.51 0.39 0.45	0.23 0.31 0.26	1.13 1.32 1.59	1.88 2.20 1.86

TABLE II. MINERAL AND NITROGEN STATUS OF APPLE FLESH SAMPLES UNDER DIFFERENT FERTILIZER TREATMENTS (ALL RESULTS ON THE DRY MATTER BASIS)

Treatment	Date of Sampling	Total Ash	Insol. Ash	Sol. Ash	CaO	MgO	P ₂ O ₅	K ₂ O	N ₂
		(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
No Fertilizer	29/4/47 9/3/48	0.96 1.30	0.06 0.03	0.90 1.27	0.060 0.067	0.046 0.043	0.08 0.10	0.57 0.67	0.20 0.22
K + N	29/4/47 27/4/48 6/4/49	1.31 1.48 2.76	0.06 0.02 0.04	1.25 1.46 2.72	0.053 0.065 0.062	0.045 0.078 0.080	0.06 0.07 0.07	0.84 0.83 0.89	0.22 0.21 0.18
P + N	29/4/47 27/4/48 6/4/49	0.93 1.59 0.95	0.06 0.04 0.03	0.87 1.55 0.92	0.054 0.066 0.072	0.040 0.061 0.054	0.09 0.08 0.10	0.35 0.64 0.45	0.26 0.25 0.28
P + K	29/4/47 27/4/48 6/4/49	1.24 2.13 2.24	0.04 0.02 0.02	1.20 2.11 2.22	0.046 0.070 0.061	0.044 0.071 0.071	0.07 0.10 0.12	0.72 0.90 0.80	0.20 0.21 0.24
P + K + N	29/4/47 27/4/48 6/4/49	1.30 1.66 2.44	0.03 0.02 0.05	1.27 1.64 2.39	0.041 0.063 0.084	0.041 0.059 0.064	0.06 0.09 0.11	0.71 0.78 0.97	0.24 0.24 0.30

TABLE III. MINERAL AND NITROGEN STATUS OF APPLE PIP
SAMPLES UNDER DIFFERENT FERTILIZER TREATMENTS (ALL
RESULTS ON THE DRY MATTER BASIS)

Treatment	Date of Sampling	Total Ash	Insol. Ash	Sol. Ash	CaO	MgO	P ₂ O ₅	K ₂ O	N ₂
		(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
No Fertilizer	29/4/47	3.23	0.06	3.17	0.35	0.34	1.29	0.82	5.06
	27/4/48	4.01	0.02	3.99	0.47	0.63	1.33	0.90	3.84
K + N	29/4/47	2.86	0.06	2.80	0.31	0.30	0.91	0.80	5.23
	27/4/48	3.79	0.04	3.75	0.41	0.61	1.26	1.04	5.98
P + N	29/4/47	3.19	0.05	3.14	0.36	0.38	1.19	0.72	4.92
	27/4/48	3.77	0.02	3.75	0.49	0.60	1.29	0.94	5.25
P + K	29/4/47	3.30	0.02	3.28	0.28	0.39	1.27	0.89	5.12
	27/4/48	3.96	0.02	3.94	0.48	0.50	1.42	1.00	5.66
P + K + N	29/4/47	2.98	0.05	2.93	0.27	0.37	1.00	0.80	4.68
	27/4/48	3.82	0.03	3.79	0.43	0.34	1.24	0.91	.

Potash

The lowest figures for potash in the leaves were associated with the "P + N" and "no fertilizer" treatments. The "P + N" treatment resulted in a lower potash status than the "no fertilizer" treatment. This is in keeping with the symptoms shown by the trees in "die-back," in small leaves and in small poorly coloured fruit. The potash figures for the "P + N" plot were less than one half of those for leaves from trees receiving potassic manures.

Phosphoric Acid

The highest content of this plant food was associated with the "P + K" treatment. In the case of the other treatments, the differences in the phosphoric acid content of leaves were comparatively small. This does not correlate satisfactorily with the poorer growth of trees on plots where phosphate has been omitted, e.g., "K + N" treatment.

Magnesia

The highest figures for magnesia were associated with the "no fertilizer" and "P + N" treatments. Wherever potash had been included in the treatment of the trees a reduction in the amount of magnesia occurred in the leaves.

Lime

The highest lime figures were associated with the "P + N" treatment while the lowest figures were found with the "K + N" treatment. The other treatments, including the "no fertilizer" plot, showed little difference in the percentage of lime in the leaves of the trees.

Soluble Ash

With the exception of the "P + N" treatment which resulted in markedly high figures for soluble ash in the leaves, the other treatments gave somewhat similar but lower figures for this constituent.

The effect of the omission of individual plant foods on the nitrogen and mineral status of the apple flesh is much less pronounced than is the case with the leaf samples.

The nitrogen figures for apple flesh samples are lowest with the "P + K" and "no fertilizer" and highest with complete and "P + N" treatments. This is different from the leaves which give the highest content with "K + N" treatment.

The potash figures for the apple flesh are lowest with "P + N" and "no fertilizer" treatments. All treatments which included potash gave relatively high potash contents.

In contrast to the results from leaf samples, the apple flesh samples with "K + N" treatment had a lower figure for phosphoric acid than with the other treatments.

In the case of magnesia and lime no marked differences in the content of these elements resulted from the omission of individual plant foods.

Soluble ash figures for the apple flesh samples showed a reduction in the amounts for the "P + N" and "no fertilizer" treatments. This reduction is connected with reduced potash content of the flesh with these treatments.

The omission of individual plant foods from the fertilizer appears to have no significant effect on the mineral and nitrogen status of the pips.

REFERENCE

1. RIGG, T., and CHITTENDEN, E. T. (1946): *N.Z. J. Sci. Tech., A*, 27, 361-71.

SOIL DISINFECTION

XI. CONTROL OF FOOT-ROT (*Phytophthora cryptogea* P. & L.) OF TOMATOES

By H. JACKS, Plant Diseases Division, Department of Scientific and Industrial Research, Auckland

(Received for publication, 19 September, 1950)

Summary

A method of controlling the spread of tomato foot-rot (*P. cryptogea*) in seedling boxes was investigated.

Out of 14 materials under test concentrations of 1 and 2 per cent. Cuprox, 0.063 per cent. Phygon, 0.25 per cent. Formalin, 1 per cent. Cheshunt Compound and 0.063 per cent. Puratized, gave satisfactory control without affecting plant growth.

Other materials such as thiram, fribam and ziram were highly effective in controlling the disease, but caused severe stunting of plants.

Cuprox was considered most satisfactory as it gave efficient control, was easy to apply and did not depress plant growth.

INTRODUCTION

HEAVY losses in stands of young tomato plants grown in seedling boxes have been reported by nurserymen. Isolations from diseased seedlings showed *Phytophthora cryptogea* Pethybr. and Laff. to be the causal organism. Investigations here described were carried out to determine a method of control for this disease other than by disinfecting soil prior to planting out of seedlings.

EXPERIMENTAL METHODS

The soil used in the trials was partially sterilized by means of a low pressure steam plant (Fig. 1), a description of which was given by Jacks and Hunter (1951). Cultures of *P. cryptogea* grown on sterilized tomato stems were macerated and then mixed with equal weights of sterile sand. This mixture was added to soil at the rate of 2 per cent. of soil weight, worked in by hand, and finally passed through a sieve to ensure even distribution. Uninoculated and inoculated soil respectively, was placed into boxes (18 × 12 × 3 in.) capable of holding 14 lb. of soil. Thirty-six tomato seedlings were planted out per box seven days after soil inoculation.

Aqueous solutions of materials listed in Table I were applied at the rate of 3 pt. (1704.6 ml.) per box five days after planting. Checks received 3 pt. water per box. Agral L, a proprietary wetting agent, was added to all solutions at the rate of 1.3 ml. per gallon. Solutions were applied through a glass funnel moved up and down the rows of plants, care being taken to avoid contact with top growth. All trials were carried out at glasshouse temperatures of 70-80°F.

Observations were made every 48 hours on :

(a) effect of inoculum on survival of seedlings ; and

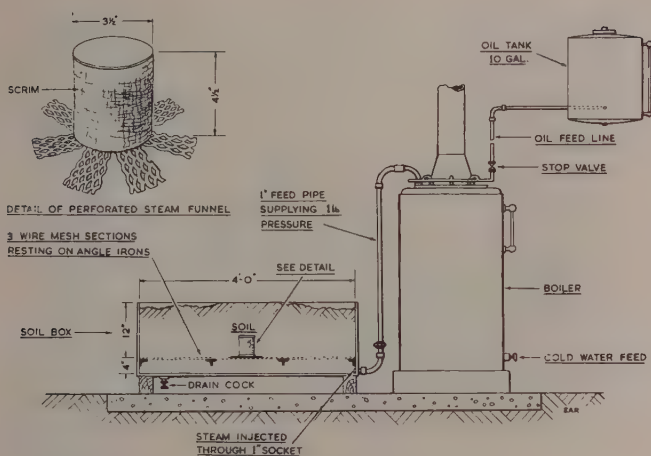
(b) effect of treatments on plant growth and spread of infection.

Results were submitted to analysis of variance. The presence of *P. cryptogea* in diseased seedlings was assessed by isolations.

TABLE I. EFFECT OF VARIOUS CONCENTRATIONS OF MATERIALS ON SURVIVAL AND GROWTH OF TOMATO SEEDLINGS PLANTED IN STERILIZED SOIL

Material.	Percentage active ingredients.	Percentage plant survival in soil watered with concentrations (%) of materials in 3 pints per box.						
		2.0	1.0	0.5	0.25	0.125	0.063	0.032
Formalin	40.0.0% formaldehyde	0.0	0.0	37.5	96.0	95.5	—	—
Sterizal	40.0.0% phenols	0.0	0.0	2.5	58.0	94.9	—	—
Nethol	1.0% methyl cellulose plus 20.0.0% ether	0.0	83.3*	96.7*	97.4*	98.3*	—	—
Ethylene dichloride	commercially pure	0.0	96.7*	97.4*	98.3*	—	—	—
Potassium permanganate	" "	98.3	100.0	100.0	100.0	—	—	—
Cheshunt Compound	15.4% copper sulphate plus 84.6% ammonium carbonate	90.0	100.0	100.0	100.0	—	—	—
Phygon	commercially pure 2,3 dichloro, 1-4 naphthoquinone	92.3*	94.9*	97.5*	93.3*	96.7	95.8	—
Spergon	commercially pure tetra-para-benzoquinone	100.0	100.0	100.0	100.0	—	—	—
Thiram	commercially pure tetra-methyl thiuram disulphide	100.0*	100.0*	100.0*	100.0*	100.0*	—	—
Firbam	commercially pure ferric-dimethyl dithiocarbamate	100.0*	100.0*	100.0*	100.0*	—	—	—
Ziram	commercially pure zinc-dimethyl dithiocarbamate	63.2*	90.5*	100.0*	100.0*	—	—	—
Panogen	0.8% alkyl mercury	60.9	76.7	100.0	100.0	—	—	—
Cuprox	50.9% copper as copper oxichloride plus 4% dispersing agent	100.0	100.0	100.0	100.0	—	—	—
Puratized	5.0% phenyl mercury triethanol ammonium lactate	0.0	0.0	18.4	51.7	66.2	95.3	95.2

* Stunted growth. NOTE: Percentage survival in controls treated with 3 pints water per box was 100 per cent.



SECTIONAL ELEVATION OF STERILIZER UNIT

FIG. 1.—Diagram of a low pressure steam plant

(Photo by S. A. Rumsey)

RESULTS

Trial 1.

This was a preliminary trial carried out to assess the range of concentrations of the different materials which could be applied without causing losses in stands of seedlings. Tomatoes were planted in partially sterilized soil and subsequently treated with materials as listed. Results are given in Table I.

Adverse effects on plant growth brought about by some materials varied from total loss of plants at the higher concentrations applied, to negligible reduction of stand at high dilutions of such substances. Other materials had no detrimental effect on stands of seedlings. Materials such as thiram, Nethol and carbamates, at all concentrations under test, brought about severe stunting of growth although not substantially affecting survival of plants. Other substances, viz. Sterizal and Puratized, gave plant damage at low concentrations such as 0.25 and 0.125 per cent. respectively. Phygon gave stunted growth of seedlings at concentrations higher than 0.125 per cent. Cuprox, Spergon, etc., did not affect plant growth.

Trials 2-5.

Soil used in these experiments was inoculated with the foot-rot organism. Treatment solutions were applied at concentrations not affecting survival of plants and results are given in Table II.

All treatments, under conditions of these experiments, brought about a significant increase in the survival of plants as compared with checks. Significance in the efficacy of various treatments in giving control of the disease was therefore measured by comparing their results with the means of all treatments. In Trials 2 and 3 materials, viz. Sterizal, ethylene dichloride, potassium permanganate, Spergon and 0.5 per cent. Cheshunt Compound, gave lower survival of plants than the means and were therefore left out from further trials. Tests were also

TABLE II. MEAN PERCENTAGE SURVIVAL OF TOMATO SEEDLINGS IN SOIL INOCULATED WITH *P. Cryptogea* AND SUBSEQUENTLY TREATED WITH VARIOUS CHEMICALS

Treatments.	Percentage concentrations in 1704.6ml. water per box.	Trial 2 Mean.		Trial 3 Mean.		Trial 4 Mean.		Trial 5 Mean.	
		Percentage Survival	Equivalent angle	Percentage Survival	Equivalent angle	Percentage Survival	Equivalent angle	Percentage Survival	Equivalent angle
Check	—	5.0	10.4	11.2	19.3	35.0	35.0	12.6	20.4
Formalin	0.250	91.7	76.3	84.4	70.8	89.1	74.0	95.5	80.0
"	0.125	96.7	83.9	91.0	76.1	69.3	56.7	—	—
Sterizal	0.125	83.3	66.3	46.7	41.6	—	—	—	—
"	0.063	86.7	68.9	42.2	40.5	—	—	—	—
Nethol	0.125	70.0*	57.1	71.7*	58.2	—	—	—	—
Ethylene dichloride	0.250	91.7	73.4	71.0	59.0	—	—	—	—
Potassium permanganate	1.000	78.0	62.0	65.1	55.2	—	—	—	—
Cheshunt Compound	1.000	90.0	72.0	84.4	69.8	91.5	73.9	93.1	75.0
"	0.500	61.2	53.1	58.8	64.7	—	—	—	—
Phygon	0.125	93.3*	75.3	88.7*	74.6	—	—	—	—
"	0.063	96.7	81.4	95.3	80.0	91.0	73.2	98.3	85.7
Spergon	2.000	66.7	55.5	69.3	56.4	—	—	—	—
Thiram	0.125	100.0*	90.0	91.0*	75.6	—	—	—	—
Firbam	0.250	98.3*	85.7	91.3*	76.1	—	—	—	—
Ziram	0.250	96.7*	83.9	89.8*	74.0	—	—	—	—
Panogen	0.500	91.7	76.3	91.0	76.7	79.1	63.8	—	—
Cuprox	2.000	96.7	81.4	86.5	73.2	93.1	75.4	99.2	87.0
"	1.000	79.8	64.7	96.6	79.5	99.2	87.0	98.0	86.5
Puratized	0.063	83.0	66.5	95.2	77.5	95.3	77.6	92.3	74.0
Means of all treatments		83.4	69.2	76.1	69.8	75.8	68.3	84.1	72.6
Difference required for significance at 5 per cent. level		—	20.3	—	23.2	—	11.1	—	14.3

* Stunted growth

discontinued with materials such as Nethol, 0.125 per cent. Phygon, thiram, firbam and ziram which affected plant growth. In Trial 4, 0.125 per cent. Formalin and Panogen proved ineffective in increasing survival of plants over the means. Finally, in Trial 5 2.0 per cent. Cuprox gave significant increase in stand of plants over means whilst effects of 1.0 per cent. Cuprox and 0.063 per cent. Phygon failed to reach significance by a very narrow margin.

CONCLUSIONS

Incidence of foot-rot of seedling tomatoes was reduced by a number of materials. Many of these, however, caused phytocidal damage and stunting of plant growth at fairly low concentrations. Satisfactory prevention of spread of the disease was obtained by application of one and two per cent. Cuprox, 0.063 per cent. Phygon, 0.25 per cent. Formalin, one per cent. Cheshunt Compound and 0.063 per cent. Puratized. Application of material solutions at these concentrations did not depress the stand of tomato seedlings. Cuprox appeared to be preferable from a practical point of view as solutions were readily prepared and did not affect plant growth at any of the concentrations tested. The effect of Cuprox in control of tomato foot-rot is shown in Fig. 2. Although plants which were already infected derived no benefit from the treatment and eventually collapsed, it was possible to prevent further spread of the disease by the application of Cuprox solutions.

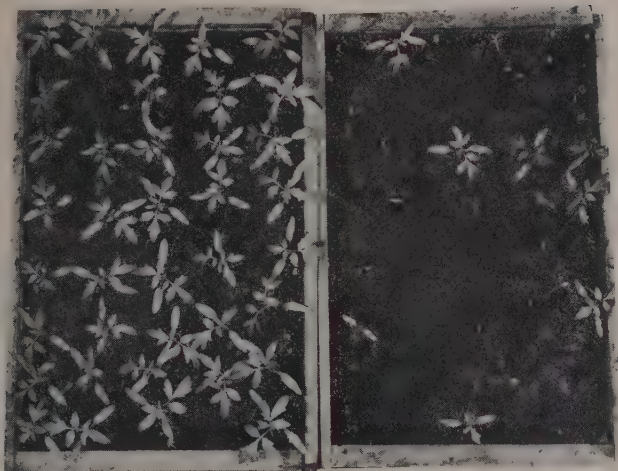


FIG. 2.—Application of Cuprox in control of foot-rot of tomatoes.
Left, untreated; Right, treated with 2 per cent. solution of
Cuprox. (Photo by S. A. Rumsey)

ACKNOWLEDGMENT

The writer is indebted to Mr. H. R. Thompson of the Applied Mathematics Laboratory for analysis of results.

REFERENCES

- JACKS, H. and HUNTER, J. A. (1951): Apparatus for low pressure steaming of Nursery Soil. *N.Z. J. Agr.*, 82, 215-6.

PEA-WILT IN NEW ZEALAND

By I. A. M. CRUICKSHANK,* Plant Diseases Division, Department of Scientific and Industrial Research, Christchurch

(Received for publication, 19 April 1950)

Summary

1. The occurrence of pea-wilt (*Fusarium orthoceras* var. *pisi*) is recorded in New Zealand, and the identity and pathogenicity of the organism is established.
2. Leaf-curling, foliage yellowing, vascular discolouration and premature death of plants are characteristic symptoms.
3. Of twenty-four varieties tested, nine garden varieties and four field varieties were found to be resistant to pea-wilt.

INTRODUCTION

PEA-WILT (*Fusarium orthoceras* Appel. et Wollenw. var. *pisi* Linford)† has been observed affecting crops in Canterbury, Auckland and Marlborough. Surveys of pea crops in these provinces during the 1948-49 and 1949-50 seasons revealed 16 severely and 6 moderately infected

* Stationed at Crop Research Division, Lincoln.

† The author is indebted to Dr. W. L. Gordon, Dominion Laboratory of Plant Pathology, Fort Garry, Manitoba, Canada, for confirmation of this identification.

crops. Severe infection caused yield-losses of 50-100 per cent. Losses in moderately infected crops were difficult to assess as pea-wilt occurred in numerous small patches irregularly scattered through the crop.

Pea-wilt, which was first described as a major disease by Linford (1928), has not previously been recorded in this country but its wide-spread occurrence at the present time indicates that it has been present in pea-growing districts for many years.

SYMPTOMS

Field Symptoms.

Symptoms of pea-wilt in a crop are not usually visible until the plants are at least six inches high, although under conditions of heavy soil infection and high soil temperature plants may show symptoms at an earlier stage of growth. Patches of diseased vines are at first stunted and pale-bluish green in colour. Their colour rapidly changes to pale yellowish-green, and then brown, as the plants die. Small to large bare patches in the crop result.

Foliage Symptoms.

Lower leaves turn brown and wither. Apical stipules and petioles of leaves curve slightly downwards and leaflets readily drop off when touched. Upper leaves turn pale yellowish green and each leaflet forms two fairly tight rolls along the dorsal surface of its main vein (Fig. 1). Plants die rapidly and turn brown.



FIG. 1.—Leaves from infected plant showing characteristic rolled position of leaflets.

(Photo by S. A. Rumsey)

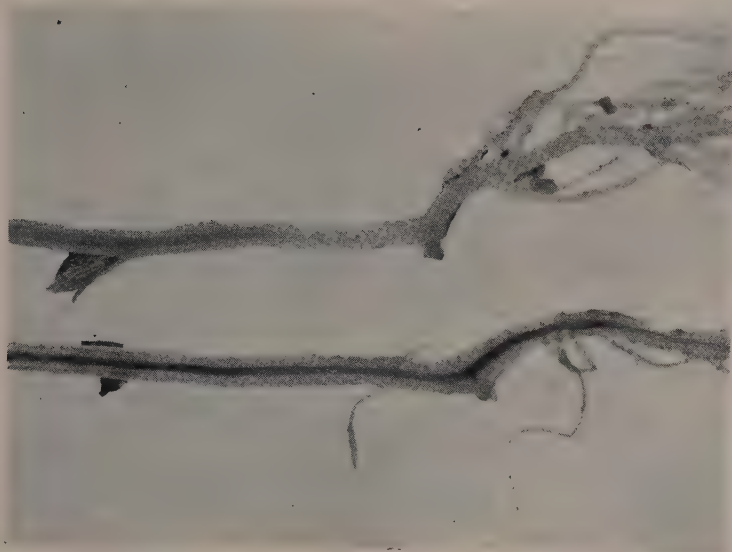


FIG. 2.—Infected stem and root showing discoloured vascular system (healthy root on right).

(Photo by S. A. Rumsey)



FIG. 3.—Pea plants showing final stages of pea-wilt (*F. orthoceras* v. *pisi*) five weeks after sowing (healthy plants in clean soil on right).

(Photo by S. A. Rumsey)

Stem and Root Symptoms.

Stems remain erect and become brittle. In the region of the hypocotyl the stem is slightly swollen, and in most specimens portions of the stele of root and stem are discoloured orange to brick red (Fig. 2). The latter symptom may be entirely absent or be very limited in extent. No foot-rot symptom is caused by pea-wilt but in the field secondary organisms may invade root tissues and cause rotting of the cortex.

DESCRIPTION OF NEW ZEALAND ORGANISM

Morphology.

No macroconidia were observed either on host tissue or culture media. This observation is in agreement with that of Linford (1928) and other authors who have studied this disease. Microconidia and chlamydospores occurred abundantly in culture on potato-dextrose agar.

Cultural Characteristics.

The fungus was grown on the following media at 25-27°C.:—potato-dextrose agar, oatmeal agar, rice agar, malt-extract agar*, Bacto-prune agar. The following cultural characters were observed:—aerial mycelium, white, abundant; macroconidia, absent; microconidia and chlamydospores, abundant on potato-dextrose agar and oatmeal agar; dark blue irregular patches beneath white aerial mycelium on potato-dextrose agar; substrate colour, vinaceous on oatmeal agar, rice agar, malt agar, and Bacto-prune agar.

EXPERIMENTAL TECHNIQUE

Pathogenicity Tests.

Seed of the variety W. F. Massey was sown in soil artificially inoculated with *F. orthocercus* v. *pisii* and plants grown under glasshouse conditions (soil temperature, 20-22°C.). Typical pea-wilt symptoms were visible 30 days after sowing (Fig. 3). The causal organism was reisolated from all infected plants. In clean soil check plants of the same variety remained healthy.

TABLE I. VARIETAL RESISTANCE OF GARDEN PEAS TO PEA-WILT
(GLASSHOUSE TRIALS)

Variety	Mean resistance* (%)	Mean equivalent angle**	Variety	Mean resistance* (%)	Mean equivalent angle**
Delwiche Commando	100	—	Laxton's Progress	90.3	72.1°
Giant Alderman	98.7	85.3°	Pioneer	23.9	29.3°
Quartermaster	97.3	83.3°	Greencrop	18.3	25.1°
Giant Stride	95.2	80.9°	Greenreast	15.1	22.7°
Yorkshire Hero	92.2	78.3°	Thomas Laxton	14.1	21.7°
Senator	94.4	76.9°	Blue Bantam	13.3	21.3°
English Wonder	88.4	75.6°	W.F. Massey	12.1	19.6°
Stratagem	92.0	74.8°	Little Marvel	12.3	19.5°
			Onward	2.3	6.3°

* Two trials, 6 pots of 8 plants in each.

** Difference for significance at 5% level: 21.0°.

* Potato dextrose agar : potato, 200 g.; dextrose, 15 g.; agar, 16 g.; water, 1,000 ml.

Oatmeal agar : oatmeal, 200 g.; agar, 16 g.; water, 1,000 ml.

Rice agar : ground rice, 200 g.; agar, 16 g.; water, 1,000 ml.

Malt extract agar : malt, 2.5 per cent.; agar, 20 g.; water, 1,000 ml.

Test for Resistance.

To test for resistance to pea-wilt, 17 garden-pea and seven field-pea varieties were grown in artificially inoculated soil in both glasshouse and field-plot trials

RESULTS AND CONCLUSIONS

The results of these trials are presented in Tables I, II, IIIa and IIIb.

Analysis of the results shows that in New Zealand the following varieties are resistant to pea-wilt:—

Garden varieties: Delwiche Commando, Giant Alderman, Quarter-master, Giant Stride, Yorkshire Hero, Senator, English Wonder, Strata-gem, Laxton's Progress.

Field varieties: Marathon, Harrison's Glory, Blue Prussian and Mammoth White.

TABLE II. VARIETAL RESISTANCE OF FIELD PEAS
TO PEA-WILT (GLASSHOUSE TRIALS)

Variety	Mean resistance* (%)	Mean equivalent angle**
Marathon	95.7	78.1°
Harrison's Glory	81.5	64.5°
Blue Prussian	74.0	59.3°
Mammoth White	58.1	49.9°
White Prolific	10.9	19.3°
Mammoth Blue	8.0	11.8°
Partridge	2.1	5.9°

*Two trials, 6 pots of 8 plants in each.

**Difference for significance at 5% level: 21.0°

ACKNOWLEDGMENTS

The author wishes to acknowledge assistance of officers of the Crop Research Division, Department of Scientific and Industrial Research and the executive of Messrs. Arthur Yates and Co., Auckland, for supplying seed, and to thank Mr. H. R. Thompson, Applied Mathematics Laboratory, Department of Scientific and Industrial Research, for statistical analysis of results.

REFERENCES

- LINFORD, M. B. (1928): *Wis. Agr. Expt. Sta. Res. Bull.* 85.

TABLE III. VARIETAL RESISTANCE OF PEA VARIETIES TO PEA-WILT

(a)				(b)		
Variety	Mean resistance * (%)	Mean equivalent angle **		Variety	Mean resistance * (%)	Mean equivalent angle **
Delwiche Commando	100	.		Harrison's Glory	98.6	86.1°
Senstor	100	.		Marathon	92.4	75.9°
Quartermaster	100	.		Blue Prussian	77.1	62.0°
Lexton's Progress	100	.		Mammoth White	70.7	57.5°
Giant Aldermen	100	.		Blue Bentam	2.1	3.5°
Yorkshire Hero	99.3	87.9°		White Prolific	1.4	2.8°
Giant Stride	99.2	87.9°		Pertridge	0	.
Strategem	97.8	85.1°		Green Crop	0	.
English Wonder	78.9	69.9°		Little Marvel	0	.
Greenfeast	0	.		Pioneer	0	.
W.F. Massey	0	.		Thomas Laxton	0	.
Onward	0	.		Mammoth Blue	0	.

* Mean of 6 rows of 25 plants per row.

** Difference for significance at 5% level: (a) 16.3°; (b) 8.6°.

BULLETINS OF THE DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

- No.
- 1-4. (Out of print.)
 5. PLANT-BREEDING METHODS AND RESULTS. F. W. Hilgendorf. Price, 6d.
 6. REPORT ON THE FISCHER PROCESS. H. O. Askew. Price, 6d.
 7. NEW ZEALAND WOOL FIBRES. (Out of print.) E. F. Northcroft. Price, 6d.
 8. SUMMARY OF INVESTIGATIONS ON NEW ZEALAND COAL. W. Donovan. Price, 6d.
 - 9-10. (Out of print.)
 11. BUILDING STONES OF NEW ZEALAND. P. Marshall. Price, 4s.
 12. REPORT OF THE NUTRITIVE VALUE OF MEAT MEALS. (Out of print.) E. A. Pope.
 13. YIELD OF CHEESE PER POUND OF BUTTERFAT. P. O. Veale. Price, 9d.
 14. LOW TEMPERATURE CARBONIZATION OF NEW ZEALAND COALS. 1. WAIKATO COAL. W. A. Joiner. Price, 9d.
 15. PEACH CULTURE. (Out of print.) K. M. Curtis and T. Rigg. Price, 1s.
 16. COLD STORAGE OF FRUIT INVESTIGATIONS OF 1927 AND 1928. L. W. Tiller. Price, 6d.
 17. PIG RECORDING, BACON-MANUFACTURE, AND THE PIG INDUSTRY IN NEW ZEALAND. M. J. Scott, C. R. Barnicoat, and F. R. Callaghan. Price, 1s 6d.
 18. GOITRE IN SCHOOL-CHILDREN. (Out of print.) R. A. Shore and R. L. Andrew.
 19. MOUTERE HILLS PASTURES. T. Rigg and H. O. Askew. Price, 9d.
 20. LOW TEMPERATURE CARBONIZATION OF NEW ZEALAND COALS. 2. KAITANGATA AND LINTON COALS. W. A. Joiner. Price, 6d.
 - 21-2. (Out of print.)
 23. RELATION OF STORAGE TEMPERATURE TO THE OVERSEAS CARRIAGE OF SOME VARIETIES OF NEW ZEALAND EXPORT APPLES. L. W. Tiller. Price, 6d.
 24. A CLASSIFICATION OF THE WAIKATO TYPE OF COAL. W. H. Penseler. Price, 1s 9d.
 25. BRONZE BEETLE RESEARCH. A. M. Lysaght. Price, 1s 6d.
 26. INFLUENCE OF SEASON AND FERTILIZER ON THE YIELD AND COMPOSITION OF TYPICAL DAIRYING PASTURES. T. Rigg. Price, 2s.
 27. TREATMENT AND DISPOSAL OF DAIRY WASTE WATERS. (Out of print.)
 28. WHEAT RESEARCH INSTITUTE: FIRST ANNUAL REPORT, 1929-30.
 29. LOW TEMPERATURE CARBONIZATION OF NEW ZEALAND COALS. 3. MILLERTON AND BLACKBALL COALS. W. A. Joiner. Price, 1s.
 30. WOOL RESEARCH.
 31. INVESTIGATIONS INTO PASTURE PRODUCTION. A. W. Hudson. Parts I, II, III issued. Price, 5s.
 32. BUSH SICKNESS. H. O. Askew, T. Rigg, L. I. Grange, N. H. Taylor, and others. Price, 2s 9d.
 33. BUTTERFAT LOSSES IN BUTTERMILK. W. H. Udy. Price, 1s.
 34. NUTRITIVE VALUE AND VITAMIN EFFICIENCY OF NEW ZEALAND DAIRY PRODUCE.
 35. WHEAT RESEARCH INSTITUTE: SECOND ANNUAL REPORT, 1930-31. F. W. Hilgendorf. Price, 1s 6d.
 - 36-8. (Out of print.)
 39. BRIQUETTING OF NEW ZEALAND COALS. W. A. Joiner, W. G. Hughson, and A. K. R. McDowell. Price, 9d.
 40. GOLD-BEARING CONGLOMERATES OF CENTRAL OTAGO. E. O. Macpherson. Price, 9d.
 - 41-3. (Out of print.)
 44. THE COMMERCIAL RIPENING OF BANANAS IN NEW ZEALAND. J. B. Hyatt and C. W. O. Turner. Price, 1s.
 45. GOITRE IN SCHOOL-CHILDREN. R. A. Shore and R. L. Andrew. Price, 1s 6d.
 46. "CROSS 7" WHEAT. O. H. Frankel. Price, 1s.
 47. THE GRASSLANDS OF THE SOUTH ISLAND OF NEW ZEALAND. (Out of print.)
 48. WATER-SUPPLIES OF FARMS AND DAIRY FACTORIES IN HAMILTON BASIN AND HAURAKI LOWLAND. N. H. Taylor. Price, 1s 6d.
 49. INTRODUCTION TO THE GRASSES OF NEW ZEALAND. (Out of print.) H. H. Allan.
 50. THE CHEESE YIELDING CAPACITY OF MILK. F. H. McDowall. Price, 3s 6d. (Obtainable from the Dairy Research Institute, Massey College, Palmerston North.)
 51. THE CHILLING OF BEEF FOR EXPORT. C. R. Barnicoat. Price, 1s 3d.
 52. INVESTIGATION OF FEED FLAVOUR IN CREAM AND BUTTER. W. Riddet, E. Bruce Levy, and others. Price, 1s.
 53. A PRELIMINARY SURVEY OF THE CITRUS INDUSTRY IN NEW ZEALAND.
 54. THE LITTLE BARRIER ISLAND. (Out of print.)
 55. THE WEST NELSON EARTHQUAKES OF 1929.
 56. WHEAT RESEARCH INSTITUTE: FOURTH ANNUAL REPORT. (Out of print.)
 57. REPORT OF INTERDEPARTMENTAL COMMITTEE ON SILICOSIS. Price, 1s 3d.
 - 58-9. (Out of print.)
 60. PETROLEUM IN NEW ZEALAND. J. Henderson. Price, 1s.
 61. THE SOILS AND AGRICULTURE OF WESTERN SAMOA. W. M. Hamilton and L. I. Grange. Price, 1s.
 62. LAND DETERIORATION IN THE HEAVIER RAINFALL DISTRICTS OF NEW ZEALAND.
 63. REPORT ON THE ORGANIZATION OF ANIMAL RESEARCH IN NEW ZEALAND. J. Hammond. Price, 1s.
 64. GENETICS AND LIVE-STOCK PRODUCTION. (Out of print.) F. W. Dry.
 65. SOIL SURVEY OF DUVAUCHELLE BAY-WAINUI DISTRICT, BANKS PENINSULA. C. S. Harris and A. C. Harris. Price, 1s 3d.
 66. A SURVEY OF TUNG GROVES IN NEW ZEALAND. M. M. Burns and N. H. Taylor. Price, 2s.

BULLETINS OF THE DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH—Continued

No.

67. A LIST OF PLANT DISEASES RECORDED IN NEW ZEALAND. R. M. Brien. Price, 1s.
68. WHEAT RESEARCH INSTITUTE: FIFTH ANNUAL REPORT. Price, 1s.
69. SCIENTIFIC AND INDUSTRIAL RESEARCH, 1927-38. Price, 2s 6d.
70. LAND UTILIZATION REPORT OF THE HERETAUNGA PLAINS. (Out of print.)
71. SOIL SURVEY OF WESTPORT DISTRICT. C. S. Harris and A. C. Harris. Price, 1s 6d.
72. SOIL SURVEY OF WAIRAU PLAINS, MARLBOROUGH. C. S. Harris and K. S. Birrell. Price, 2s.
73. SURVEY OF THE TUSsock-GRASSLANDS OF THE SOUTH ISLAND, NEW ZEALAND. V. D. Zotov. Price, 1s.
74. SOME GROUND-WAVE FIELD-INTENSITY MEASUREMENTS TAKEN IN NEW ZEALAND. G. Searle. Price, 1s.
75. A SURVEY OF THE STANDARDS OF LIFE OF NEW ZEALAND DAIRY-FARMERS. W. T. Doig. Price, 2s 6d.
- 76-9. (Out of print.)
80. THE CURING AND COLOURING OF NEW ZEALAND LEMONS. J. B. Hyatt and O. H. Keys. Price 1s.
81. WHEAT RESEARCH INSTITUTE: SIXTH ANNUAL REPORT. (Out of print.) Price, 1s.
82. BOTANICAL ASPECTS OF RAGWORT (*SENECIO JACOBAEA* L.) CONTROL. A. L. Poole and D. Cairns. Price, 2s 6d.
83. A HANDBOOK OF THE NATURALIZED FLORA OF NEW ZEALAND. H. H. Allan. (Out of print.) Price, 10s and 10s 6d.
84. WHEAT RESEARCH INSTITUTE: SEVENTH ANNUAL REPORT. Price, 1s.
85. THE ECONOMIC IMPORTANCE OF SEAWEEDS. (Out of print.) L. B. Moore.
86. MOLE DRAINAGE IN NEW ZEALAND.
87. WHEAT RESEARCH INSTITUTE: EIGHTH ANNUAL REPORT. (Out of print.)
88. FIRECLAY AND GANISTER IN NEW ZEALAND. J. Henderson. Price, 2s 6d.
89. THE DAIRY INDUSTRY IN NEW ZEALAND. W. M. Hamilton. Price, 2s 6d.
90. MILBURN-CLARENDON PHOSPHATE DEPOSITS. E. O. Macpherson. Price, 2s 5d.
91. NASSELLA TUSsock. A. J. Healy. Price, 2s 9d.
92. SOIL EROSION IN THE HIGH COUNTRY OF THE SOUTH ISLAND. H. S. Gibbs, J. D. Raeside, J. K. Dixon, and A. J. Metson. Price, 5s.
93. INVESTIGATION OF THE CLARENDON PHOSPHATE DEPOSITS. R. W. Willett. Price, 5s.
94. SOILS AND SOME RELATED ASPECTS OF AGRICULTURE IN MID HAWKE'S BAY. I. J. Pohlen and others. Price, 5s.
95. SOIL EROSION IN NEW ZEALAND—PART 1: SOUTHERN HALF OF NORTH ISLAND. L. I. Grange and H. S. Gibbs. Price, 2s 6d.
96. RHYTHMS IN NEMATODE PARASITISM OF SHEEP. J. H. Tetley. Price, 3s 6d.
97. REPORT ON BUILDING AND CIVIL ENGINEERING RESEARCH IN NEW ZEALAND. R. E. Stradling. Price, 2s 6d.
98. INTRODUCED MAMMALS OF NEW ZEALAND. K. A. Wodzicki. Price, 12s 6d.

ALL PRICES POST FREE

NEW ZEALAND JOURNAL OF SCIENCE AND TECHNOLOGY. [Vols. 1-32.]

Vol. 33 now appearing

ANNUAL SUBSCRIPTION—Volume 33, Section A (Agricultural Research Section), 10s.
Section B (General Research Section), 10s. Sections A and B, 15s. Single copy, 2s;
Postage 1d. (See inside front cover.)

Order through your Bookseller or from

**THE PUBLICATIONS OFFICER, DEPARTMENT OF SCIENTIFIC
AND INDUSTRIAL RESEARCH, P.O. BOX 562, DUNEDIN**

and from

**THE HIGH COMMISSIONER FOR N.Z.,
415 STRAND, LONDON, W.C.2**

All Orders should be accompanied by remittance. To country cheques add exchange (6d.)